Some Account Of The
Life 1873 Vol. I

SOME ACCOUNT

OF

THE LIFE, &c.

MR. JOHN SMEATON, F.R.S. a very celebrated Civil Engineer, and author of the enſuing Reports, was born the 28th of May, 1724, at *Auſthorpe*, near *Leeds*, *Yorkſhire*, in a houſe built by his grandfather, where the family have reſided ever ſince, and where our author died the 28th of October, 1792, in the 68th year of his age.

Mr. SMEATON ſeems to have been born an Engineer. The originality of his genius and the ſtrength of his underſtanding appeared at a very early age. His playthings were not thoſe of children, but the tools men work with; and he had always more amuſement in obſerving artificers work, and aſking them queſtions, than in any thing elſe. Having watched ſome mill-wrights at work, he was one day, ſoon after, ſeen (to the diſtreſs of his family) on the top of his father's barn, fixing up ſomething like a windmill. Another time, attending ſome men who were fixing a pump at a neighbouring village, and obſerving them cut off a piece of bored pipe, he contrived to procure it, of which he made a working pump, that actually raiſed water. Theſe anecdotes refer to circumſtances that happened when he was hardly out of petticoats, and probably before he had reached the 6th year of his age. About his 14th or 15th year, he made for himſelf an engine to turn roſe-work, and he made ſeveral preſents to his friends of boxes, in wood and ivory, turned by him in that way.

His friend and partner in the *Deptford* Water-works, Mr. JOHN HOLMES, viſited Mr. SMEATON, and ſpent a month with him at his father's houſe, in the year 1742, when conſequently our author was about 18 years of age.

Mr. HOLMES

Mr. HOLMES could not but view young SMEATON's works with aſtoniſhment: he forged his own iron and ſteel, and melted his own metals: he had tools of every ſort for working in wood, ivory and metals. He had made a lathe, by which he had cut a perpetual ſcrew in braſs, a thing very little known at that day.

Thus had Mr. SMEATON, by the ſtrength of his genius, and indefatigable induſtry, acquired, at 18 years of age, an extenſive ſet of tools, and the art of working in moſt of the mechanical trades, without the aſſiſtance of any maſter, and which he continued to do a part of every day when at the place where his tools were; and few men could work better.

Mr. SMEATON's father was an attorney, and was deſirous of bringing his ſon up to the ſame profeſſion. He was therefore ſent up to London in 1742, where for ſome time he attended the courts in *Weſtminſter-Hall*; but finding that the profeſſion of the law did not ſuit *the bent of his genius*, (as his uſual expreſſion was,) he wrote a ſtrong memorial to his father on the ſubject, whoſe good ſenſe from that moment left Mr. SMEATON to purſue the bent of his genius in his own way.

Mr. SMEATON after this continued to reſide in *London*, and about the year 1750 he commenced philoſophical inſtrument maker, which he continued for ſome time, and became acquainted with moſt of the ingenious men of that time.

This ſame year he made his firſt communication to the Royal Society; being an account of Dr. KNIGHT's improvements, of the Mariner's Compaſs. Continuing his very uſeful labours, and making experiments, he communicated to that learned body, the two following years, a number of other ingenious improvements, as will be enumerated in the liſt of his writings, at the end of this account of him.

In 1751 he began a courſe of experiments, to try a machine of his invention for meaſuring a ſhip's way at ſea; and alſo made two voyages, in company with Dr. KNIGHT, to try it, as well as a compaſs of his own invention.

In

In 1753 he was elected a member of the Royal Society; and in 1759 he was honoured with their gold medal, for his paper concerning the natural powers of water and wind to turn mills, and other machines depending on a circular motion. This paper, he says, was the result of experiments made on working models in the years 1752 and 1753, but not communicated to the Society till 1759; having, in the interval, found opportunities of putting the result of these experiments into real practice, in a variety of cases, and for various purposes, so as to assure the Society he had found them to answer.

In 1754, his great thirst after experimental knowledge led him to undertake a voyage to Holland and the Low Countries, where he made himself acquainted with most of the curious works of art so frequent in those places.

In December 1755, the *Edystone Lighthouse* was burnt down, and the proprietors, being desirous of rebuilding it in the most substantial manner, enquired of the Earl of MACCLESFIELD, then President of the Royal Society, who he thought might be the fittest person to rebuild it; when, he immediately recommended our author. Mr. SMEATON accordingly undertook the work, which he completed with stone in the summer of 1759. Of this work he gives an ample description in a folio volume, with plates, published in 1791; a work which contains, in a great measure, the history of four years of his life, in which the originality of his genius is fully displayed, as well as his activity, industry and perseverance.

Though Mr. SMEATON completed the building of the *Edystone Lighthouse* in 1759, yet it seems he did not soon get into full business as a Civil Engineer; for in 1764, while in *Yorkshire*, he offered himself a candidate for one of the receivers of the *Derwentwater* estate; in which he succeeded, though two other persons, strongly recommended and powerfully supported, were candidates for the employment. In this, he had the faithful and friendly support of Sir FRANCIS GOSLING, Alderman of *London*, and one of the Commissioners. That estate was forfeited in the year 1715, and the revenues thereof were applied by Parliament, towards the fund of *Greenwich Hospital*. It consists of mines of lead, containing much silver, as well as lands.

 It

It required, better than common management, and above all, that knowledge abſolutely neceſſary to bring mines of lead and coal to the moſt productive effect. This was the object of the Commiſſioners, and it has been amply repaid. Machines of all kinds, and better means on a great plan, were deviſed for a more eaſy and ample working theſe mines, by Mr. SMEATON: while, the correct judgment, patient induſtry, and great abilities and ſincerity of Mr. WALTON the younger, of *Farnacres* near *Newcaſtle*, (his partner in the duty of receiver,) taking upon himſelf the management and the accounts, left Mr. SMEATON, leiſure and opportunity, to exert his abilities on theſe works, as well as to make many improvements in the whole of this eſtate of *Greenwich Hoſpital*.

By the year 1775 he had ſo much buſineſs, as a Civil Engineer, that he was deſirous of reſigning the appointment for that Hoſpital, and would have done it then, had not his friends prevailed upon him, to continue in the office about two years longer.

Mr. SMEATON having thus got into full buſineſs as a Civil Engineer, it would be an endleſs taſk to enumerate all the various concerns he was engaged in. A very few of them however may be juſt mentioned in this place. —He made the river *Calder* navigable; a work that required great ſkill and judgment, owing to the very impetuous floods in that river.—He planned, and attended for ſome time, the execution of the great, or *Forth* and *Clyde*, canal in *Scotland*, for conveying the trade of the country either to the *Atlantic* or *German Ocean*. When this work had been executed from the *Forth* towards the *Clyde*, as far as a point intended for the junction of a collateral canal to *Glaſgow*, the work ſtopped, and was diſcontinued a conſiderable time, by the funds being exhauſted. Before that period, Mr. SMEATON had declined accepting his ſalary, which was five hundred pounds a year, that he might not be prevented from attending to the multiplicity of other buſineſs; and conceiving the reſident engineer, Mr. M'KELL, was fully competent to conduct it afterwards. After a lapſe of ſome time, the work was reſumed, by public aid, and has been carried on, and lately completed, under the direction of Mr. WHITWORTH, to the great benefit of trade and that country.

On

On opening the great arch at *London Bridge*, by throwing two arches into one, and the removal of a large pier, the excavation, around and underneath the ſterlings of that pier, was ſo conſiderable, as to put the adjoining piers, that arch, and eventually the whole bridge, in great danger of falling. The previous opinions of *ſome* were poſitive, and the apprehenſions of *all* the people on this head were ſo great, that many perſons would not paſs over or under it. The Surveyors employed were not adequate to ſuch an exigency. Mr. SMEATON was then in *Yorkſhire*, where he was ſent for by expreſs, and from whence he arrived in town with the greateſt expedition. He applied himſelf immediately to examine the bridge, and to ſound about the dangerous ſterlings, as minutely as he could. The Committee of Common Council adopted his advice; which was, to re-purchaſe the ſtones of all the City Gates, then lately pulled down, and lying in *Moorfields*, and to throw them pell-mell, (or *piere perdu*,) into the water, to guard theſe ſterlings, preſerve the bottom from further corroſion, raiſe the floor under the arch, and reſtore the head of water neceſſary for the water-works to it's original power; and this was a practice, he had before, and afterwards adopted on other occaſions. Nothing ſhews the apprehenſions of the bridge falling, more, than the alacrity with which his advice was purſued: the ſtones were re-purchaſed that day; horſes, carts, and barges were got ready, and the work inſtantly begun, though it was Sunday morning. Thus Mr. SMEATON, in all human probability, ſaved *London Bridge* from falling, and ſecured it till more effectual methods could be taken.

In 1771 he became, jointly with his friend Mr. HOLMES above-mentioned, proprietor of the works for ſupplying *Deptford* and *Greenwich* with water; which, by their united endeavours, they brought to be of general uſe to thoſe they were made for, and moderately beneficial to themſelves.

Aſtronomy was one of Mr. SMEATON's moſt favorite ſtudies; and he contrived and made ſeveral aſtronomical inſtruments for himſelf and friends. After fitting up an obſervatory at his houſe at *Auſthorpe*, he devoted much of his time to it when he was there: even in preference to public buſineſs, much of which he declined for the purpoſe of applying his attentions to private ſtudy, particularly to the ſubject of aſtronomy.

 About

About the year 1785 Mr. SMEATON's health began to decline; and, in consequence, he then took the resolution to avoid new undertakings in business as much as he could, that he might thereby also have the more leisure to publish some accounts of his inventions and works. Of this plan, however, he got no more executed than the account of the *Edystone Lighthouse*, and some preparations for his intended treatise on mills; for he could not resist the solicitations of his friends in various works. Mr. AUBERT, whom he greatly loved and respected, being chosen chairman of *Ramsgate Harbour*, prevailed upon him to accept the office of Engineer to that harbour, an office established at that time, as, he had been occasionally consulted only, previous thereto; and to *their joint efforts* the public are chiefly indebted for the improvements that have been made there, within these few years; which fully appears in a Report that Mr. SMEATON gave in to the Board of Trustees in 1791, which has been published in various ways.

The powers of his mind were beginning to fail, in the observation of his intimate friends, and afterwards of all. He is known to have said, on talking of his health, that he found he had suffered more from the application he paid to the scheme, design, and proposition of a Canal from *Birmingham* to *Worcester*, (which was then very much contested in Parliament) than all the business he had ever met with.

Strong exertions were necessary; which, if he had been vigorous as he was wont, it would have sat easy upon him; but alas! with the deficiency then commenced, it was hard labour indeed, and thereby promoted, the ruin fast approaching, and much to be lamented.

This lamentable tale is told, for the instruction of *those* engaged, and so circumstanced, at that period of life, when the powers of the mind are borne down by the complication and vastness of an object submitted to it.

The bill for that work passed by a small majority; but the difficult and contested part of that work has not as yet been attempted. He was not the proposer, but the supporter of that proposition.

It

It had for many years been the practice of Mr. SMEATON to ſpend part of the year in town, and the remainder in the country, at his houſe at *Auſthorpe*. On one of theſe excurſions in the country, while walking in his garden, on the 16th of September, 1792, he was ſtruck with the palſy, which put an end to his uſeful life the 28th of October following, to the great regret of a numerous ſet of friends and acquaintance.

The great variety of mills conſtructed by Mr. SMEATON, ſo much to the ſatisfaction and advantage of the owners, will ſhew the great uſe he made of his experiments in 1752 and 1753. Indeed he ſcarcely truſted to theory in any caſe where he could have an opportunity to inveſtigate it by experiment; and for this purpoſe he built a ſteam-engine at *Auſthorpe*, that he might make experiments expreſsly to aſcertain the power of the OLD or NEWCOMEN'S ſteam-engine; which he improved and brought to a much greater degree of certainty, both in it's conſtruction and powers, than it was before.

During many years of his life, Mr. SMEATON was a conſtant attendant on Parliament, his opinion being continually called for. And here his natural ſtrength of judgment and perſpicuity of expreſſion had their full diſplay. It was his conſtant practice, when applied to, to plan or ſupport any meaſure, to make himſelf fully acquainted with it, and be convinced of it's merits, before he would be concerned in it. By this caution, joined to the clearneſs of his deſcription, and the integrity of his heart, he ſeldom failed, having the bill he ſupported, carried into an act of Parliament. No perſon was heard with more attention, nor had any one ever more confidence placed in his teſtimony. In the Courts of Law he had ſeveral compliments paid to him from the Bench, by the late Lord MANSFIELD and others, on account of the new light he threw upon difficult ſubjects.

As a Civil Engineer, he was perhaps unrivalled, certainly not excelled, by any one, either of the preſent or former times. His building the *Edyſtone Lighthouſe*, were there no other monument of his fame, would eſtabliſh his character. The *Edyſtone Rocks* have obtained their name from the great variety of contrary ſets of the tide or current in their vicinity. They are

ſituated nearly S. S. W. from the middle of *Plymouth Sound*. Their diſtance from the port of *Plymouth* is about fourteen miles. They are almoſt in the line which joins the *Stert* and the *Lizard Points*; and as they lie nearly in the direction of veſſels coaſting up and down the *Channel*, they were unavoidably, before the eſtabliſhment of a lighthouſe there, very dangerous, and often fatal to ſhips. Their ſituation, with regard to the *Bay of Biſcay* and the *Atlantic*, is ſuch, that they lie open to the ſwells of the bay and ocean, from all the ſouth-weſtern points of the compaſs; ſo that all the heavy ſeas, from the ſouth-weſt quarter, come uncontrolled upon the *Edyſtone Rocks*, and break upon them with the utmoſt fury. Sometimes, when the ſea is to all appearance ſmooth and even, and it's ſurface unruffled by the lighteſt breeze, the ground ſwell meeting the ſlope of the rocks, the ſea beats upon them in a frightful manner, ſo as not only to obſtruct any work being done on the rock, or even landing upon it, when, figuratively ſpeaking, you might go to ſea in a walnut ſhell. That circumſtances, fraught with danger ſurrounding it, ſhould lead mariners to wiſh for a lighthouſe, is not wonderful; but the danger attending the erection leads us to wonder, that any one could be found hardy enough, to undertake it. Such a man was firſt found in the perſon of Mr. H. WINSTANLEY, who, in the year 1696, was furniſhed by the *Trinity Houſe* with the neceſſary powers. In 1700 it was finiſhed; but in the great ſtorm of November, 1703, it was deſtroyed, and the projector periſhed in the ruins. In 1709 another, upon a different conſtruction, was erected by a Mr. RUDYERD, which, in 1755, was unfortunately conſumed by fire.

The next building was under the direction of Mr. SMEATON, who, having conſidered the errors of the former conſtructions, has judiciouſly guarded againſt them, and erected a building, the demolition of which ſeems little to be dreaded, unleſs the rock on which it is erected ſhould periſh with it. Of his works, in conſtructing bridges, harbours, mills, engines, &c. &c. it were endleſs to ſpeak.

Of his inventions and improvements of philoſophical inſtruments, as of the air-pump, the pyrometer, hygrometer, &c. &c. ſome idea may be formed from the liſt of his writings inſerted below.

In his perſon, Mr. SMEATON was of a middle ſtature, but broad and ſtrong made, and poſſeſſed of an excellent conſtitution. He had great ſimplicity and plainneſs in his manners: he had a warmth of expreſſion that might appear, to thoſe who did not know him well, to border on harſhneſs; but, ſuch as were more cloſely acquainted with him, knew it aroſe from the intenſe application of his mind, which was always in the purſuit of truth, or engaged in the inveſtigation of difficult ſubjects. He would ſometimes break out haſtily, when any thing was ſaid that was contrary to his ideas of the ſubject; and he would not give up any thing he argued for, till his mind was convinced, by the deducement of facts, before unknown to him, and by ſound reaſoning. In all the ſocial duties of life, Mr. SMEATON was exemplary; he was a moſt affectionate huſband, a good father, a warm, zealous, and ſincere friend, always ready to aſſiſt thoſe he reſpected, and often before it was pointed out to him in what way he could ſerve them. He was a lover and an encourager of merit wherever he found it; and many perſons now living are in a great meaſure indebted for their preſent ſituation to his aſſiſtance and advice. As a companion, he was always entertaining and inſtructive, and none could ſpend their time in his company without improvement.

As to the liſt of his writings; beſides the large work above-mentioned, being the Hiſtory of the *Edyſtone Lighthouſe*, and numbers of Reports and Memorials, many of which were printed, his communications to the Royal Society, and inſerted in their Tranſactions, are as follow:

1. An Account of Dr. KNIGHT's Improvements of the Mariner's Compaſs. An. 1750, pa. 513.
2. Some Improvements in the Air-Pump. An. 1752, pa. 413.
3. An Engine for raiſing Water by Fire; being an Improvement on SAVARY's Conſtruction, to render it capable of working itſelf; invented by M. DE MOURA, of *Portugal*. Ib. pa. 436.
4. Deſcription of a new Tackle, or Combination of Pulleys. Ib. pa. 494.
5. Experiments on a Machine for meaſuring the Way of a Ship at Sea. An. 1754, pa. 532.

6. Deſcription

6. Defcription of a new Pyrometer. Ib. pa. 598.

7. Effects of Lightning on the Steeple and Church of *Leftwithial* in *Cornwall.* An. 1757, pa. 198.

8. Remarks on the different Temperature of the Air at *Edyftone Lighthoufe* and at *Plymouth.* An. 1758, pa. 488.

9. Experimental Enquiry concerning the natural Powers of Water and Wind to turn Mills, and other Machines depending on a circular Motion. An. 1759, pa. 100.

10. On the Menftrual Parallax arifing from the mutual Gravitation of the Earth and Moon, it's Influence on the Obfervation of the Sun and Planets, with a Method of obferving it. An. 1768, pa. 156.

11. Defcription of a new Method of obferving the Heavenly Bodies out of the Meridian. An. 1768, pa. 170.

12. Obfervations on a Solar Eclipfe. An. 1769, pa. 286.

13. Defcription of a new Hygrometer. An. 1771, pa. 198.

14. An Experimental Examination of the Quantity and Proportion of Mechanical Power neceffary to be employed in giving different Degrees of Velocity to heavy Bodies from a State of Reft. An. 1776, pa. 450.

CONTENTS.

The COMMITTEE of CIVIL-ENGINEERS.

Fellfoot, near *Kendal*, 30th October, 1797.

GENTLEMEN,

THE advertisement relative to the publication of Mr. SMEATON's works, recalls to my mind a request made from you, through Mr. BROOKE, "that his daughters would assist in furnishing any anecdotes illustrative of "his life and character." And this recollection calls upon me to apologize for the apparent neglect, as well as to account why an office so pleasant could be delayed for a moment. The fact is, Gentlemen, that, however immediate the impulse was to act about it, I soon found, in so doing, the task at once difficult and delicate.

The public ear, I am afraid, is satiated and fastidious; and the plain anecdotes of a plain man, like him, though interesting to individuals, could awaken little public curiosity, or perhaps, give still less satisfaction when awakened. And, extraordinary as it may seem, his family, probably less than others, are in possession of anecdotes concerning him; for, though communicative on all subjects, and stored with ample, and liberal observations on others; of *Himself*, he never spoke. In nothing does he seem to have stood more single, than in being devoid of that egotism, which, more or less, affects the world. It required some address, even in his family, to draw him into conversation directly relative to himself, his pursuits, or his success. Self-opinion, self-interest, and self-indulgence, seemed, alike, tempered in him, by a modesty inseparable from merit,—a moderation in pecuniary ambition,—a habit of intense application, and a temperance strict beyond the common standard. And, it is owing, perhaps, to this regulation, that, through a course of incessant fatigue, and incredible exertion, from *six years old to sixty*, the multiplicity of business, and pressure of cares, never had power to deaden his affections, or injure his temper.

I say,

I ſay, "*ſix years old to ſixty*," becauſe while in petticoats, he was continually dividing circles and ſquares; all his play-things were models of machines, which deſtroyed the fiſh in the ponds, by raiſing water out of one into another. At ſchool;—his exerciſes, in the law, to him not an agreeable deſtination; his dry, though uſeful attainments, occupied him through the day;—but mechanics, and his favourite ſtudies, engroſſed the chief of every night. So that his mind appears to have indured an inceſſant exertion through that period.

It was his maxim, "that the abilities of the individual, were a *debt* "due to the common ſtock of public happineſs, or accommodation!" This appears to have governed his actions through life; for the claim of ſociety (thus become ſacred) his time was devoted to the cultivation of talents, by which he might benefit mankind; and thenceafter, to the unwearied application of them.——

Indefatigable in the purſuits they led to, the public are in poſſeſſion of all which Nature intruſted to him, or the meaſure of life allowed.

His friends know well how to appreciate the honeſt man, who valued them! And what he was in his family, every member of it could ſpeak, if called upon, with equal gratitude, pride, and pleaſure!

The arrangement of his time was governed by a method, as invariable as inviolable: for profeſſional ſtudies were never broken in upon, by any one; and theſe, (with the exception of ſtated aſtronomical obſervations,) wholly ingroſſed the forenoon. His meals were temperate, and for many years reſtricted, on account of health, to *rigid* abſtinence, from which he derived great benefit.

His afternoons were regularly occupied by practical experiments, or ſome other branch of mechanics. And not more entirely was his mind devoted to his profeſſion in one diviſion of his time, than abſtracted from it

in

in another. *Himself* devoted to his family with an affection so lively, a manner at once so cheerful and serene, that it is impossible to say, whether the charm of conversation, the simplicity of instructions, or the gentleness with which they were conveyed, most endeared his home. A home, in which from infancy we cannot recollect to have seen a trace of dissatisfaction or a word of asperity to any one. Yet with all this he was absolute! And it is for casuistry in education, or rule, to explain his authority; it was an authority, as impossible to dispute as to define.

The command of his feelings, and submission of a temper, naturally warm, to reason and benevolence, were strongly illustrated by a circumstance, (in my recollection,) peculiarly trying to him. It arose from the conduct of a man formerly employed as a clerk, in whom having the highest confidence and esteem, he procured him a similar, though more lucrative, situation in a public office; where he served with a fidelity which in time promoted him to a station, of high trust and responsibility, (my father being bound, jointly with another gentleman, for his conduct, in a considerable sum.) It were needless to say by what degrees in error this man fell; it suffices, that at last he forged a false statement, to meet the deficiency; that he was detected, and given up to justice. The same post brought news, of the melancholy transaction; of the man's compunctions and danger; of the claim of the bond forfeited; and of the refusal of the other person to pay the moiety! — Being present when he read his letters, which arrived at a period of Mrs. SMEATON's declining health, so entirely did the command of himself second his anxious attention to her, that no emotion was visible on their perusal; nor, till all was put into the best train possible, did a word, or look, betray the exquisite distress it occasioned him. In the interim, all which could soothe the remorse of a prisoner, every means which could save, (which did, at least from public execution,) were exerted for him, with a characteristic benevolence, " active and unobtrusive."

The disinterested moderation of his pecuniary ambition, every transaction in private life evinced; his public ones bore the same stamp: and after his health had withdrawn him from the labours of his profession, many instances may be instanced by those, whose concerns induced them to press importunately for a resumption of it; and when some of them, seemed disposed to enforce their entreaties by further prospects of lucrative recompence, his reply was strongly characteristic of his simple manners and moderation. He introduced the old woman, who took care of his chambers in *Gray's Inn*, and shewing *her*, asserted, "that her attendance sufficed for "all his wants." The inference was indisputable, "for money could not "tempt that man to forego his ease, leisure, or independence, whose "requisites of accommodation were compressed within such limits!"

Before this, the Princess De Askoff made an apt comment upon this trait of his character; when, after vainly using every persuasion to induce him to accept a *carte blanche* from the Empress of Russia, (as a recompence for directing the vast projects in that kingdom,) she observed, "Sir, you are "a great man, and I honour you! You may have an equal in abilities, per-"haps; but in *character* you stand single. The *English* minister, Sir Robert "Walpole, was mistaken, and my sovereign has the misfortune to find "*one Man* who has *not* his price!"

Early in life he attracted the notice of the late Duke and Duchess of Queensbury, from a strong resemblance to their favourite Gay, the poet. The commencement of this acquaintance was singular, but the continuance of their esteem and partiality lasted through life.—Their first meeting was at *Ranelagh*, where, walking with Mrs. Smeaton, he observed an elderly lady and gentleman fix an evident and marked attention on him. After some turns they at last stopped him, and the Duchess (of eccentric memory) said, "Sir, I dont know who you are or what you are, but so strongly do "you resemble my poor dear Gay, we *must* be acquainted; you shall go "home and sup with us; and if the minds of the two men accord, as do "the countenance, you will find two cheerful old folks, who can love you

"*well*;

" *well*, and I think, (or you are an hypocrite,) you can *as well* deserve it."—The invitation was accepted, and, as long as the DUKE and DUCHESS lived, the friendship was as cordial as uninterrupted; indeed, their society had so much of the *play* which genuine wit and goodness know how to combine, it proved to be, among the most agreeable relaxations of his life.—A sort of amicable and pleasant hostility was renewed, whenever they met, of talent and good humour; in the course of which, he effected the abolition of that inconsiderate indiscriminate play, amongst people of superior rank or fortune, which compels every one to join, and at their own stake too.—My father detested cards, and his attention never following the game, played like a boy. The game was *Pope Joan*, the general run of it was high, and the stake in "*Pope*" had accidentally accumulated to a sum *more* than serious. It was my father's turn by the deal, to *double it*, when, regardless of his cards, he busily made minutes on a scrap of paper, and put it on the board. The DUCHESS eagerly asked him what it was? and he as coolly replied; " Your Grace will recollect the field in which my house stands may be " about 5 acres, 3 roods and 7 perches, which, at thirty years purchase, " will be just my stake, and if your Grace *will make a Duke of me*, I pre-" sume the winner will not dislike my mortgage."—The joke and the lesson had alike their weight; they never after played but for the merest trifle.

The manly simplicity of deportment to his superiors, however, was alike free from pretension and servility; and an invariable consideration and kindness to his inferiors, produced a singular sentiment of veneration, in those who served him.

He always apprehended the stroke which terminated his life, as it was hereditary in his family; he dreaded it *only* as it gave the melancholy possibility of out-living his faculties, or the power of doing good: to use his own words, " *lingering over the dregs, after the spirit had evaporated!*"

When this really did happen, the composure, with which he met it; his anxious endeavour to soften any alarm to his family; his resignation to the event; and his dignified thankfulness on finding at last, his intellect was spared,

were

were every way worthy of himself.—Still his invariable wish was, "*to be* "*released!*"

In the interim, (six weeks) all faculties, and every affection, were as clear and animated, as at any period of his life. His memory was tenacious, and his ingenuity as active to relieve the inconveniencies of his then situation, as such situation gave what *he* termed, trouble to those about him.——

He expressed a particular desire and pleasure, in seeing the usual occupations resumed; and reading, drawing, music and conversation excited the same interest, the same cheerful and judicious observations as ever.

He would sometimes complain of his own slowness, (as he called it,) of apprehension, and then would excuse it with a smile, saying, "It could "not be otherwise, the shadow *must* lengthen, as the sun went down!" There was no *slowness* in fact to lament; for he was as ready at calculations, and as perspicuous in explanation, as at any former period. Some phenomena respecting the moon were asked him one evening, when it accidentally shone bright, full into his room. When he had spoke fully on them, his eyes remained fixed upon it with a most animated attention, to us impressive; then turning them, on us with benignity, observed, "How often "have I looked up to it with inquiry and wonder! To the period, when I "shall have the vast and privileged views of an HEREAFTER, and all will "be comprehension and pleasure!"

Shortly after, the end he had through life desired, was granted; the body gradually sunk, but the mind shone to the last; and in the way good men aspire to, he closed a life, active as useful, amiable as revered!

MARY DIXON.

CONTENTS.

CONTENTS.

d

The

Proposals

Page

Th

Eſtimate

The

REPORTS, &c.

QUESTIONS propoſed by the Magiſtrates and Town-Council of *Dumfries* to the conſideration of MR. SMEATON. October, 1760.

1ſt. WHAT is the eaſieſt and moſt effectual method for preſerving the town's grounds of *Kingholme* from the future encroachments of the river?

2d. How can the navigation of the river *Nith* be moſt eaſily improved from *Kingholme* to *Kelton*, and the channel rendered leſs precarious than it is at preſent?

3d. It is deſired that MR. SMEATON may viſit the works carried on in the under part of the river, oppoſite to the Merſe grounds of *Netherwood*, *Cargin*, and *Lagball*; and, upon conſidering the courſe of the river, and the ſituation and extent of theſe works, to give his opinion how far the navigation of the river will be bettered or injured by ſuch works; and what amendments or alteration of them are neceſſary for preſerving the navigation entire? And in caſe ſuch works are attempted to be made by other heretors, what orders ought the Magiſtrates and Town-Council to give thereanent, as being guardians of the public navigation of this river; and how many feet or fathom broad ought the channel to be kept free at thoſe places?

In caſe it ſhall be thought proper or neceſſary that any of the works already erected ought to be deſtroyed, whether ſhould the ſtakes be pulled up or knocked down, equal to or below the ſurface of the ground where they now are; and what ought to be done with ſuch parts of the works as are of ſtone?

EBEN. HEPBURN.
JOHN DICKSON.
WM. CLARK.

ANSWERS to the queſtions propoſed by the Magiſtrates and Town-Council of *Dumfries*, for the conſideration of J. SMEATON.

HAVING carefully examined the courſe of the river *Nith* and the banks thereof, from *Dumfries* to *Kirkonnel* on the Weſt ſide, and from *Kelton* to *Dumfries* on the Eaſt, both upon the flood and ebb of a ſpring tide, I am of opinion as follows:

Anſwer to queſtion 1.—Where the banks, by the undermining of the water, tumble down, I would adviſe them to be ſloped as low down as where the water begins to act, and to defend the foot of the ſlope by rows of ſtakes, ſingle or double, according to the violence of the water's action, placed in a direction parallel to the bank, with binders to confine down a lay of faſcines pointing towards the water. The ſlope of the bank muſt not be greater than to incline five feet backward for every yard of perpendicular height; the ſurface of this ſlope to be ſodded, ſown with hay ſeeds, or otherwiſe graſſed over as far as the graſs will grow, and the remainder covered with gravel, laid partly upon the faſcines. The directions of the rows of ſtakes ought to be ſuited to the direction of the water, attempting as much as poſſible a right line or fair curve, avoiding as much as poſſible all ſudden turns and irregularities.

Anſwer to queſtion 2.—*The channel of the river Nith has ſo many ſudden turns and* irregularities, that the tide ſpends itſelf among the ſinuoſities of the river, and in filling up wide ſpaces above, after having paſſed through narrower below, and is thereby prevented from mounting to ſo great a perpendicular height as it would otherwiſe attain, in the upper parts of the river near *Dumfries* in caſe the courſe was more ſtraight, and had a more regular contraction; and this diſadvantage is ſtill the greater, as the ſpace of time occupied by the tide of flood is ſo ſhort, that it begins to ebb below, before the loops of the river, in the ſuperior part, have time to fill to the level that the ſurface had been at in the lower, at high water. The navigation, therefore, ſeems incapable of any great improvements at any moderate expence, otherwiſe than by cutting a navigable canal, with proper locks and other works upon it, which can be done for much leſs than it would coſt to make the river itſelf tolerably regular. But the way to prevent it from growing worſe than it now is, muſt be by hindering it from becoming ſtill more crooked, and growing ſtill more wide above than below, giving as free a paſſage as poſſible to the tide of flood, eſpecially in the moſt contracted places. Whatever contributes to this end tends to preſerve it; whatever has a contrary effect muſt be a detriment to it.

Anſwer to queſtion 3.—In viſiting thoſe grounds and works, I obſerved as follows. That *Cargin* Merſe being ſituated on the concave ſide, or in the very bottom of a conſiderable

fiderable loop of the river, the direction which the current receives from the fuperior grounds, on tide of ebb, and from the inferior, on tide of flood, both ftrongly tend to carry away the land of *Cargin* Merfe, and thereby to render the loop ftill deeper: I am therefore of opinion, that the jettys and works there conftructed, in as much as they contribute to prevent this loop from growing deeper, that is, the river from growing more crooked, they thereby contribute to the benefit of the navigation. But I am of opinion, that thofe jettys have been advanced too far into the river, whereby the courfe of the water has, in that part, been too much contracted; and alfo that, by being placed acrofs the direction of the ftream, they have contributed to hinder the free paffage of the tide of flood, which would of confequence not fill the upper part of the river to fo great a perpendicular height, as has been already mentioned. However, as thofe jettys have in fome meafure anfwered one good purpofe, viz. that of preventing the river from falling into a deeper loop in that place, and as it might be of dangerous confequence to difturb the body of fleech there gathered, by totally rooting up thofe jettys, I am of opinion, that fuch of the jettys as run acrofs, or intercept the current, fhould be levelled with the prefent furface of the fleech, which may be done either by driving down or fawing off the ftakes. As to the jettys that have been formed on the *Netherwood* fide, as they don't feem to have contributed to fave the land, or to have anfwered any one purpofe whatfoever, nor do they feem to produce any other effect than that of contracting the river in this, the otherwife narroweft part, and that of intercepting the current on tide of flood, both which, confidering the large wide bay juft above, and the various meandrings ftill higher, together with the fmallnefs of the time that the tide of flood acts at this place, I am of opinion, that thofe jettys are very prejudicial to the navigation, and therefore think, that all of them, whether of wood or ftone, fhould be pulled up, or otherwife levelled with the prefent bed of the river on which they ftand. As to the jettys and works which have been raifed upon the Merfe grounds of *Laghall*, fuch as are contiguous to thofe of *Cargin* fhould be ferved in the fame manner as has been mentioned concerning thofe of *Cargin*; but as to the reft, they are either fo inconfiderable, or fo placed, as to produce no fenfible effect on the navigation. With refpect to future works for preferving or gaining of land, provided they are fo contrived as to fhorten the courfe of the current, leaving the channel of the river of fuch a width, as to be wider than the medium width of half a mile above, and narrower than the medium width for half a mile below; at the fame time carrying the weir fence, or advanced work, parallel to the natural direction of the current, reducing it, as near as may be, to a right line or fair curve, without fudden elbows and irregularities; laying alfo the banks or interior works fmooth, and floping, fo as not to catch hold of and entangle the current of the tide of flood: I am of opinion, that all fuch works ought to be encouraged, as being advantageous to the navigation of the river.

Auftborpe, 28th Nov. 1760. J. SMEATON.

QUESTIONS offered by ROBERT MAXWELL of *Cargin* to the confideration of Mr. SMEATON.

THE Merfe grounds of *Cargin* belonging to MR. MAXWELL, are fituated on the weft fide of the river *Nith*, oppofite to the Merfe belonging to Mr. JOHNSTON, of *Netherwood*, on the eaft fide of the river.

The Merfe of *Cargin* for many years had been greatly injured by the river, until MR. MAXWELL raifed weirs, or fmall creals, for defending his property from future encroachment. MR. JOHNSTON, late of *Netherwood*, made works of the fame nature on his fide, which extend a confiderable way higher up the river than MR. MAXWELL's, and oppofite to works of the like conftruction erected on the other fide by MR. CORRIE, an heretor adjoining to *Cargin*, on the north or upper fide.

While thefe works were carrying on, the Town Council (as guardians of the navigation of the river) interpofed their authority, and, on a vifitation thereof, appointed certain parts of the works, on both fides, to be removed, as being prejudicial to the public navigation. This order having been intimated to the whole heritors concerned, they agreed to comply therewith, and became bound in writing to remove the works pointed out as being fo injurious. Accordingly MESSRS. MAXWELL and CORRIE did remove fuch parts of their works as were ordered, and fixed pofts or pearches on what remained, for the direction of mariners. The other heretor, MR. JOHNSTON, did not remove a ftick or ftone of his; on the contrary, his heir and fucceffor is now infifting to have the whole of MR. MAXWELL's works removed, as being hurtful to his, Mr. JOHNSTON's, property, and to the public navigation.

It is therefore defired that MR. SMEATON will view the works on both fides, and, upon confidering the fituation and extent of them, to give his anfwer to the following queftions.

1ft. How far were thefe works neceffary for preferving the Merfe of *Cargin*; and how can they be further fecured, without injuring the navigation of the river, or the private property of others?—In confidering this queftion it is to be obferved, that by the fituation of the oppofite grounds of *Netherwood*, and the higher works thereon, which extend far into the channel, the force of the land flood and ebb tide, as well as the current of the flowing tide, is thrown with much violence on the bofom of *Cargin* Merfe, which has nothing but

thefe

theſe works to repel the force of it; ſo that MR. SMEATON will pleaſe to conſider what would have been the natural conſequence had ſuch work not been made.

Queſtion 2.—How far are the works on *Cargin* ſide prejudicial to public navigation? And pleaſe alſo conſider whether works of this kind, raiſed in defence of private property, are illegal and unprecedented; and whether they tend to hurt public navigation, and injure the private property of an oppoſite heretor.

QUESTIONS offered by ROBERT MAXWELL, of *Cargin*, anent his work on the ſide of the river *Nith*, to the conſideration of MR. J. SMEATON.

IT is deſired that MR. SMEATON, in viſiting the river, will view and conſider the courſe of the river, the floods and tide, and the ſituation of the grounds and works conſtructed thereon, upon the Merſes of *Cargin* and *Netherwood*, and give his anſwers to the following queſtions.

1ſt. Whether from the courſe of the river, and the ſituation of the oppoſite ground, the Merſe of *Cargin* is expoſed to the force of the land flood and ebb tide, and alſo to the current of the flowing tide; and if works were not therefore neceſſary, for defending *Cargin* Merſe from the future encroachments of the river?

2d. Whether the work already erected on *Cargin* Merſe can hurt or prejudice the oppoſite Merſe of *Netherwood*; and whether theſe works can be deemed illegal and unprecedented, as being injurious to the oppoſite grounds?

3d. How can theſe works be ſecured or improved, in the eaſieſt and moſt effectual manner, for preſerving *Cargin* Merſe, without injuring public navigation, or the private property of neighbouring heretors?

ROBERT MAXWELL.

ANSWER

ANSWERS to the Queſtions offered by ROBERT MAXWELL of *Cargin*, anent his Works on the ſide of the River *Nith*, by JOHN SMEATON.

Anſwer to Queſtion 1ſt.

CARGIN Merſe laying in the bottom, or moſt concave part, of a conſiderable loop of the River *Nith*, is by its ſituation expoſed to the principal action of the flood and ebb tides, and alſo to that of the land floods; and the natural ſoil being of a very looſe nature, artificial works were abſolutely neceſſary, for the defence thereof from future encroachments of the river, as without this, the natural effect of the currents would be, to make this loop of the river ſtill deeper, by carrying away the ſoil of *Cargin* Merſe.

Anſwer to the 2d queſtion.—As *Cargin* Merſe, notwithſtanding what has been done, is ſtill on the concave ſide of a deep loop of the river, the principal force of the current is ſtill exerted on that ſide; and as the oppoſite grounds lay upon the convex ſide, they cannot be ſenſibly affected thereby; and thoſe above, or below this concavity, are at too great a diſtance,to be thereby affected. Works for this purpoſe are frequently made, and if not advanced further than what has been known to have been firm ground in the memory of man, I apprehend cannot be deemed illegal; but this part of the queſtion more properly belongs to the laws.

Anſwer to the 3d. queſtion.—By making the weirs parallel to the direction of the current, ſo as to make, as much as poſſible, a right line or fair curve, and ſloping the banks, covering the ſame with faſcines and gravel, except on ſuch places as they can be graſſed over.

Auſthorpe, 28th November, 1760. J. SMEATON.

To

On the water-werks at *Halifax*.

To Mr. SIMPSON.

SIR,

INCLOSED you have a ſketch of the method which I would propoſe for laying of the pipes of the intended Water-works at *Halifax*, and an eſtimate referring thereto, which I hope will be near the matter, having ſpent ſome time in the conſideration and forming thereof; however, I would not wholly rely upon my own judgment, but deſire that thoſe papers may be overlooked and conſidered by my ingenious friend JOSEPH KNIGHT, whoſe natural ſagacity and acquirements in theſe kinds of affairs will, I am perſuaded, lead him to diſcover and point out ſuch overſights and miſtakes as I may have been guilty of, notwithſtanding the care I have taken; and I muſt take this opportunity of deſiring, that, though the Gentlemen have thought proper to conſult me on this occaſion, I may not be conſidered as any bar to his merit, but rather as jointly concerned.

It may not be amiſs, however, to point out the general principle upon which I have conducted myſelf; and, in the firſt place, as the town lays very unequal in point of level, and, of conſequence, a very great perpendicular preſſure will lay upon the pipes, eſpecially towards the lower parts, I have endeavoured to avoid the additional expence, that naturally would ariſe from proportional encreaſe of thickneſs, by taking advantage of ſuch circumſtances in the ſituation, as have a tendency to relieve the diſadvantages thereof; and, with this view, I have aſſigned the bores of the pipes in general conſiderably leſs than I ſhould have done, in caſe the town had been more upon a level, becauſe the declivity has a tendency to force the water through the pipes with greater velocity, and make them give as much water through a given orifice, as would be done by a larger pipe more upon a level, and with a leſſer preſſure upon it.

2dly. Conſidering that the ſupply will come from above the head of the town, and that the pipe of conduct, at its firſt entrance into the town, muſt carry all the water neceſſary for the ſupply of the whole, but that in going lower down it has only the water to convey for ſuch parts as lay ſtill lower; of conſequence, the neceſſary bore of the pipe of conduct will grow leſs and leſs the further and lower it goes; but as it is a certain principle in hydraulics, that pipes become ſtronger in proportion as their diameters are leſs, when the thickneſs of the ſhell of the metal is the ſame, it follows, that if their bores are diminiſhed in proportion as their perpendicular preſſure is increaſed, the ſmaller pipe will be as able to ſuſtain its weight of water as the larger will be to ſuſtain the preſſure peculiar thereto;

thereto: for these reasons, instead of adding to the weight of metal as we go lower down, I have proposed the same thickness for the main all the way, and by diminishing the diameter, and consequently the weight, have added the necessary strength; by which advantage a great weight of metal will be saved, without injury to the main design. As to the branches, I have proportioned their thickness to the thickness of that part of the main which is upon the same level, regard being had to the difference of their bores; by these means every part of the system of pipes will be equally strong, with respect to the stress that will come upon it. I don't mean, however, that every part is adjusted with a mathematical exactness; for as I have allowed every part to be considerably stronger than what may be barely called sufficient, that would be not only unnecessary, but by making every yard of pipe of different bore and thickness, would be more unreasonably troublesome in the execution. That that part of the main which lays between the reservoir at the *Gibbet*, and the back street, I have supposed of the same bore and thickness all the way, for the ease of calculation; but, in reality, I propose it to be considerably wider towards the reservoir, yet, as the pressure diminishes that way, it can be done with the same metal as the calculation supposes.

3dly. Considering, likewise, the inequality of the ground in another view, in case there should be, at any time, any defect in point of quantity furnished to the reservoir for the supply of the whole town, it is evident that the lower parts of the town would be first supplied, because the water will naturally run down hill, and accumulate in the lowest parts first, by which means the lower parts would be well supplied, when the upper parts were partially, or scarce at all supplied: and even when the reservoir would furnish as much water as the pipes could take, as the water would issue with much greater velocity from the lower cocks than from the higher; should many of the lower cocks be open together, this would still abate the issuing of the water from the higher, and especially those at a distance from the main, so that while the lower cocks were kept running in this manner, the upper ones would be but faintly supplied; for remedying of which defects, as well as others that would accrue from the sensible effects of the leakage and waste of all the cocks in the town at once, I propose to part the town into two divisions, the upper and the lower, to receive the water alternately: the upper division to consist of all the streets above the Hall end, and the lower division of all below, which will be done by placing a stop-cock upon the main at ⁎ ⊕, and three others at the three principal branches at ⊕ A, ⊕ B, and ⊕ C; by which means, the ⁎ cock being shut, and A, B, and C open, the upper division will be served alone: on the contrary, the cocks A B C being shut, and the ⁎ cock open, the lower division will be served, and no part of the upper. And here it must be remarked, that I propose the two streets,

called

called the bottom of *Gibbet-lane* and the *Swine-market*, to be ferved out of the branches p r, p m, and not from the main A B, B C; for otherwife, thofe two ftreets, with the upper branches dependant thereon, would be perpetually fupplied, whereas the fupply of every other part of the town would be intermitted, and confequently the diftribution unequal.

The equality propofed hereby might, perhaps, be ftill greater, in cafe the town was divided into more divifions than two; but as the fcheme would be embarraffed with a greater number of branches and ftop-cocks, I was unwilling to deftroy its fimplicity for trifling advantages. Perhaps the divifion that I have propofed may not confift of an equal value of water-rents; but as this may be adjufted by proportioning the time that each divifion fhall receive the water, I would rather propofe this method of preferving the equality, than by taking any other point of divifion, which, as the town is fhaped, I think would not be fo convenient.

4thly. Refpecting the method of conveyance of the water from the fpring to the refervoir; though I am ftill of opinion it may effectually be done in a gutter lined with clay and gravel; yet, confidering that this gutter muft be covered, and well fecured from evaporation and diverfion, I have, upon fecond thoughts, (at leaft for the fake of coming to an eftimate) fuppofed this conveyance to be in wooden pipes of four inches bore, which there is no doubt will anfwer, and not give the water any ill tafte, as the defcent from *Broadby Laith* to the *Gibbet* is great enough to give the water a rapid current, confequently its time of continuance in the pipes will probably not exceed half an hour.

5thly. I have only further to obferve, that I have not included the purchafe in my eftimate, which, added to the amount thereof, will make a fum much beyond what feemed to be imagined when I was at *Halifax*; and, on this account, I have been the more minute, and have inclofed a copy of the amount of each particular part of the lead-work, that in cafe I have inferted or omitted any ftreet which ought to have been otherwife, a proper correction may be made; and alfo that the whole may be fubmitted to examination, from whence I flatter myfelf it will appear that the matter is not exaggerated. And I am, with the utmoft refpect to the gentlemen promoters of this fcheme,

SIR,

Your moft humble fervant,

J. SMEATON.

C P. S. Pleafe

P. S. Pleafe to tell my friend, Mr. STANSFIELD, that the improvements I fuppofed might be made in fulling as well as other mills, when this matter came in queftion on the *Calder*, is no longer a matter of theory; and, contrary to the determination of Mr. BANKS, *that a fulling-mill is a machine fo fimple, that it is not capable of any farther improvement*, a fulling-mill that has been erected from one of my plans, in dry times, goes with lefs than a quarter of the ufual quantity; and in frefhes goes with 3 feet 8 inches tail water; though the greateft difference between head and tail water, when the laft is moft down, in dry feafons, never exceeds 4 feet 6 inches.

ESTIMATE for the Water-works at *Halifax*.

	£.	s.	d.
To expences in walling and fecuring the fpring head, - - - - - -	30	0	0
To piping from *Broadby Lauth-fpring* to the *Gibbet*, being two miles, to be wood pipe four inches bore, laying and compleating, at 5 *s.* per yard, - - - -	880	0	0
To erecting a water-houfe and refervoir near the *Gibbet*, - - - - - -	200	0	0
To 653 cwt. of lead piping in the main, leading from the refervoir to *Smithy Stake*, folder-work, laying, and making good the ftreets, at 1 *l.* 4 *s.* per cwt. - - -	783	12	0
To 931 cwt. in the branches at ditto, - - - - - - -	1117	4	0
To four large brafs ftop-cocks and a valve, at 4 *l.* each, - - - -	20	0	0
	3030	16	0
To unforefeen expences, at 10 per cent. - - - - - -	303	0	0
	3333	16	0

London, 14th February, 1761.

Place.

Place.	Bore.	Thickness.	Length. Ch.	Length. L.	Weight. lbs.	C.	qrs.	lbs.
* A	3½	½	12	10	25,555			
A B	3½	½	2	80	5,914			
B C	3¼	½	5	85	11,624			
C D	3	½	5	30	9,864			
D E	2¾	½	3	13	5,433			
E F	2½	½	3	18	5,123			
F G	2¼	½	3	10	4,604			
G H	2	½	3	68	5,005			
			39	14	73,122 =	652	3	14
Branches.								
A a	2½	⅜	4	81	5,714			
a b	2¼	5/16	2	52	2,223			
B b	2¼	5/16	6	00	5,292			
C b	2¼	⅜	7	23	7,852			
b c d b	2	¼	13	00	7,937			
e f	1¾	¼	1	92	1,042			
g h i	1¾	5/16	8	62	6,141			
k l	2	5/16	2	76	2,201			
l m	1¾	5/16	5	00	3,562			
n o	1½	¼	2	85	1,354			
p q	1¾	¼	4	00	2,171			
r s	1½	¼	1	75	831			
p r	2¼	5/16	2	90	2,558			
r m	2¼	⅜	6	00	6,516			
t v	2¼	⅜	3	20	3,475			
v w	2	5/16	8	00	6,378			
v x	1¾	5/16	4	10	2,921			
v E	1½	5/16	5	10	3,200			
D y	2¼	7/16	3	00	3,870			
y z	2	⅜	5	30	5,215			
R V	1½	5/16	1	50	941			
S T	1½	5/16	2	60	1,632			
E N O G	1¼	⅜	9	20	8,115			
Q P	1½	5/16	2	40	1,506			
H M	1½	⅜	3	60	2,808			
H I	1¼	7/16	2	17	2,282			
I K K L	1½	7/16	7	00	6,528			
			126	53	104,265 =	930	3	21
			165	67	177,387	1583	3	7

N. B. The Mark * is supposed to be placed at the *Gibbet*.

PROPOSALS for building an engine for raiſing water 11 feet from the well or reſervoir, into the piece of water in the gardens of Her Royal Highneſs the DOWAGER PRINCESS OF WALES, at *Kew*, to be worked by one large or two light horſes.

THE following things are ſuppoſed to be done at the expence of Her Royal Highneſs: The drain or gutter, leading from the engine to the *Chineſe* houſe to be lowered four feet; the ground to be cleared and levelled for the engine to ſtand upon; the earth to be wharfed up with brick-work; the well cleaned, and the brick-work repaired, where neceſſary; and, in caſe it is thought expedient to underpin the groundſill of the ſhade with brick, the materials to be led from the river to the place, and the labourers to aſſiſt in lifting and digging what may be required during the ſetting up.—The engine to work with an *Archimedes* ſcrew, 2 feet 8 inches diameter, and 24 feet long; the ſhade for the horſes to be 30 feet from out to out, and the mean diameter of the horſe track 24 feet.

This engine to raiſe 1200 hogſheads in four hours, with one large horſe or two light ones, ſuch as have heretofore been uſed.

A ſmall pump, to be worked occaſionally by the engine, for raiſing water from the gutter to the ciſtern, in the kitchen garden.

The whole of the machinery and frame-work thereof, with the ſhade for the horſes walk, and a cover from the ſcrew, with a ciſtern and ſluice at the foot thereof, to be completed in the moſt ſubſtantial and workman-like manner, for the ſum of one hundred and fifty pounds.

The REPORT of JOHN SMEATON, Engineer, concerning the practicability, &c. of a navigable canal from *Wilden* ferry, in the county of *Derby*, to *King's Bromley* common, near *Litchfield*; and from thence in feveral branches, the firft leading to *Longbridge*, near *Burflem*, the fecond to *Newcaftle under Line*, the third to the city of *Litchfield*; and the fourth to the river *Tame*, at or near *Fazeley* bridge, near *Tamworth*, all in the county of *Stafford*, as projected by MR. JAMES BRINDLEY, Engineer.

HAVING, in company with Mr. BRINDLEY and Mr. HENSHALL, land furveyor, in the month of November, 1760, carefully viewed and confidered the tracts of ground through which the canal abovementioned and its branches are propofed to pafs, and compared the fame with the plans and levels produced by Meffrs. BRINDLEY and HENSHALL; and alfo viewed the courfe of the rivers, (*Trent* and *Tame*) as well as the feveral brooks, ftreams, water-courfes, and whatever elfe feemed principally to relate to the abovementioned project, it appears to me as follows:

1ft. That the waters that are or may be collected into the brooks, at the head of the propofed canal and its feveral branches, are refpectively fufficient to fupply the fame with water; and that the canal and its branches, as projected by Mr. BRINDLEY, are practicable, and may be executed at the feveral expences contained in an eftimate bearing the fame date as this report.

2d. That as the river *Trent* appears to have few pools naturally navigable, in proportion to its extent, and thofe of no great length, but on the contrary abounds with fhoals, is in many places very winding, in general runs in a fhallow channel, and is fubject to continued floods; in confequence a new canal will anfwer the purpofes of a navigation, in the prefent cafe preferable to carrying the fame more generally through the mother river, and which, for a great part of the tract in queftion, is impracticable at any tolerable expence.

3d. That, in particular, the prefent navigable part of the *Trent*, between *Wilden* ferry and *Burton*, is fo much obftructed by fhoals and fcours, that the purpofes thereof would be much more effectually anfwered by the canal projected by Mr. BRINDLEY.

4th, That

4th. That the tracts of ground through which the canal abovementioned and its branches are proposed by Mr. BRINDLEY to pass, are well chosen, and for the greatest part well adapted by nature for such a purpose, and as little injurious to private property as the nature of such a work will admit of; MR. BRINDLEY having judiciously designed the course thereof to pass through a great number of level commons and waste grounds, and, in general, through the most barren lands that could be found in any wise to agree with the course thereof.

5th. That a branch from the canal to *Longbridge* may be conducted upon a dead level from near the town of *Stoke* to the town of *Newcastle*, as laid down in the plan.

6th. That a canal from *King's Bromley* common may be conducted up the valley of *Litchfield Brooks*, to the city of *Litchfield*, but at a very moderate charge, to the tail of *Stow* pool.

7th. That a canal being conducted upon a level from some proper point of the main canal, at or near *King's Bromley* common, the same will meet the valley of the *Tame*, at or near *Fazeley* bridge; and by inverted locks a communication may be formed, and the navigation may be carried by that river to the borough of *Tamworth*, the waters being pounded up thither by the mills at *Tamworth*.

8th. That the branch of the canal, proposed to be carried to *Longbridge*, is capable of being extended, so as to join the navigable river that falls into the west sea; for it is but a little above two miles from *Longbridge*, to a meadow which lies between two hills near *Harecastle*, in which meadow the waters that run into the west sea divide from those that make their way into the east, and which therefore may be called the point of partition. The grounds between *Longbridge* and this point lie with a gentle declivity, and, according to a level taken by Mr. HENSHALL, this point of partition is elevated above that of *Longbridge* a little more than 90 feet; but as one third part of this ascent lies within a quarter of a mile of the summit, and as the ground there appears to be suitable, a considerable part of this ascent may be avoided, by a deep cut through the summit, which will be of a moderate length, as the ground seems of the same quality, and to fall away much in the same manner on the west side as on the east; and as, according to the report of those who know the grounds, particularly the meadows on the west side, are nowhere interrupted by rocks, or other remarkable obstructions, a canal is by consequence as practicable from the point of partition westward, as it is from the same point eastward; and the distance is not near so great to the navigable rivers on the west, as

on

on the eaſt. It only remains that probable means be ſhown of ſupplying this additional canal at the point of partition with water; for if this is done, the lower parts will be ſupplied of courſe: In reſpect whereof it muſt be obſerved, that the point of partition lies greatly under the level of the adjacent hills, and conſequently the ſprings iſſuing from ſuch hills may be conducted thither, and all the water upon the more elevated grounds may be intercepted for ſeveral miles round, in order to ſupply a reſervoir in a proper place, above the level of the point of partition. Theſe ſprings will be further aſſiſted by water iſſuing from the coal-pit drains that now are, and hereafter will probably be multiplied, as the grounds hereabouts abound with coal, the greateſt part of which is at preſent ungot; but ſhould all theſe reſources, in a dry ſeaſon, prove too little, the navigation may be ſupplied with water by the help of a fire engine, to return the waters from a lower level, where the collection of ſprings may at all times be ſufficient; ſo that the water may be uſed as many times over as may be needful.

9th. That from the beſt information it appears, that the preſent navigation between *Wilden* ferry and *Gainſbrough* is much obſtructed by ſhoals and ſcours, inſomuch that in ſeveral places, in the common ſtate of the river in dry ſeaſons, there is not above 8 inches depth of water, and that at ſuch times, without the aid of flaſhes from Kings mills upon the *Trent*, and the loweſt mills upon the *Derwent*, the navigation would then be impracticable.

10th. That, for theſe reaſons, the purpoſe of the canals before mentioned will not be fully and compleatly anſwered, without an amendment of the navigation between *Wilden* ferry and *Gainſbrough*, either by an extenſion of the main canal from *Wilden* ferry to the tide's way, or by ſome other means that may effectually anſwer the purpoſe; nevertheleſs, I am of opinion,

11th. That the purpoſe of the canals already mentioned will in good part be anſwered, even ſhould the obſtructions of the navigation between *Wilden* ferry and *Gainſbrough* remain as they are; for, notwithſtanding thoſe obſtructions, a large quantity of goods is navigated up this part of the river with advantage, and if a canal is compleated, on the preſent plan, to *Wilden*, it will be ſtill better worth while to conquer the difficulties attending this part, in order to get into a clear and complete navigation, that will carry goods, without obſtructions, into the heart of the kingdom, according to the printed plan; and even acroſs the kingdom, if the ſcheme ſhould take place in its full extent; and whenever that is the caſe, it is not to be doubted but means will be found of rendering the navigation between *Wilden* ferry and *Gainſbrough* equally perfect with the reſt.

12th. In

12th. In order therefore that the boats which at present navigate upon the *Trent* may navigate freely upon the new canal, I am of opinion with Mr. BRINDLEY, that the canals ought to be about 8 yards wide at the water line; and that the new canal may be of a suitable depth, when the obstructions below *Wilden* are removed, the same ought to be 2 feet 6 inches deep of water upon the fording-places, which ought to be shoalest, and 3 feet or 3 feet 6 inches in other places, to allow for mud, and sufficient freedom for the vessels; and this depth will be of advantage, notwithstanding the want of depth of water below, because the loading of two vessels from *Gainsbrough* may be put into one at *Wilden*, and the loading of two vessels at *Wilden* brought in one from above.

13th. That the lock gates being made water tight, as they are capable of being made, no mill can be deprived of any water. Farther, that one lockful to each boat, which on exact calculation is found to be a very inconsiderable quantity, in proportion to what is necessary to work a mill for 24 hours; the evaporation from the surface of the canals, and leakage through the banks into the back drains, scarcely deserve mention, with respect to their effect on the mills. As to fisheries, they cannot in any wise be affected, because the waters in the canals being nearly stagnant, and closed by the lock gates, no fish can pass either way.

14th. That the publick road being supplied with sufficient carriage bridges, the water courses with underground passages, the communication between commons and private properties by a sufficient number of fording-places, well paved and sloped, and no where above 2 feet 6 inches deep, and the banks, whenever the water of the canal is even with or above the natural soil, to be furnished with sufficient back drains, to convey any leakage of the water that may happen, to its proper and natural place of discharge; I say, things being thus provided for, public and private roads, all necessary communications between grounds and water courses will not only be preserved, and the grounds themselves freed from damage, but, on the other hand, many lands will be greatly benefited, by having plenty of good water for cattle, &c.

Austhorpe, 11th July, 1761. J. SMEATON.

General ESTIMATE for making the canals and works for compleating the navigation and branches referred to, in Mr. SMEATON's report, upon principles of estimation settled between Messrs. SMEATON and BRINDLEY.

	£.	s.	d.
1st. To making the main canal from *Wilden* Ferry to *King's Bromley* Common, being in length 25 miles, the perpendicular ascent 110 feet, with 19 locks thereon, - - -	32,054	10	0
2d. To making the great western branch, from *King's Bromley* Common to *Longbridge*, between *Burslem* and *Newcastle under Line*, being in length 30¼ miles, perpendicular ascent 166¾ feet, with 28 locks thereon, - - - - - - - -	45,384	15	0
3d. To the small branch out of the last, proceeding from *Stoke* to *Newcastle*, being in length 3½ miles, upon a dead level, without a lock, - - - - - -	3,306	6	0
4th. To making the *Litchfield* branch, from *King's Bromley* Common to the tail of *Stowpool* near *Litchfield*, being in length 2¼ miles, perpendicular ascent about 18 feet, with 3 locks thereon, - - - - - - - - - -	3,935	9	0
5th. To compleating the above into *Litchfield* mill pool, being about half a mile, and perpendicular ascent about 30 feet, with 5 locks thereon, - - - - -	3,029	18	0
6th. To making the *Tamworth* branch, from *King's Bromley* Common to *Fazeley Bridge* near *Tamworth*, being in length 10 miles, upon a dead level, without a lock, - - -	9,431	12	0
7th. To compleating the above by a cross canal into the river *Tame*, being in length half a mile, perpendicular descent 16 feet 10 inches, with 3 locks thereupon, - - -	1,995	12	0
	100,198	2	0

Austhorpe, 11th July, 1761. J. SMEATON.

THE RIVER WEAR.

The REPORT of J. SMEATON, concerning the ſituation of the firſt lock upon the river *Wear*.

HAVING, in obedience to the order of the Commiſſioners, at their laſt meeting on the 2d day of May, 1761, re-examined, as well the ſituation ſtaked out by me in November laſt, as the ſituation lately propoſed by the Gentlemen Coal Viewers, who viewed and marked out the ſame 176 yards higher up the river than the former; and having carefully examined the river in both places, and alſo at intermediate diſtances, I am humbly of opinion as follows:

1ſt. That the erection of a lock at the place marked out by me in November laſt, cannot have the leaſt tendency to prejudice the coal works underneath; for though the workings underneath are ever ſo irregular, and though a thruſt ſhould have been brought on 2 pillars 30 yards to the north of the lock, yet while thoſe pillars are capable of ſupporting the river *Wear*, they are capable of ſupporting the lock. Nor will the placing of a lock there in any wiſe tend to weaken the body of ſolid matter interpoſed between the bottom of the river and the bed of coal; for the ſill has been found in the bottom of the ſtaples at 21 feet from the ſurface of the ground, and it may be neceſſary to ſink the foundation of the lock 24 feet below the ſame ſurface; yet as the ſtaples are ſunk 18 feet, or thereabouts, more northward than the utmoſt limits of the lock wall; and ſince it appears that at the verge of the water, and within the river, the ſill lays as low, and in many places much lower than the intended foundation, there does not appear to be any occaſion to ſink into the ſill at all; and yet in caſe there ſhould be occaſion to cut half a foot, or even one foot on the north ſide, into the ſill, by way of bringing the ſame to a level, (the ſill appearing from the ſtaples to riſe with the hill towards the north) yet as this will be replaced with matter much more compact and impenetrable to water than the ſill itſelf, it is not eaſy to conceive that this can in the leaſt prejudice the reſiſtance of a body of matter 12 or 15 fathom in thickneſs, being ſo much down to the workings of the 5 quarter coal.

2dly. That it is practicable to build a lock at the place marked out by the Gentlemen Coal Viewers, 176 yards higher up the river than the former; but that ſuch ſituations will be attended with the following additional diſadvantages.

1ſt. It

1ſt. It appears, that the ſill laying at the laſt mentioned place, at a medium, 1½ feet lower than the foundation of the lock, the carrying the foundation one foot and a half lower than neceſſary, will not only be attended with a conſiderable charge, but being a quickſand down to that depth, the drainage of the water, and ſecuring the ſides of the lock-pit till the bottom is finiſhed, will be much more difficult and expenſive alſo. And laſtly, as there will be a neceſſity of making a channel for the paſſage of the veſſels on the north ſide, into the lock, from the tail of the lock, as propoſed in its former ſituation, it will therefore be neceſſary to dredge the whole diſtance of 176 yards; and not only that, but to ſecure the ſide of the channel next the river with a proper fence, to prevent its being filled with the ſilt of the river upon the firſt flood; and as this is a work capable of eſtimation, I have hereto annexed an Eſtimate thereof.

Durham, 2d June, 1761. J. SMEATON.

ESTIMATE for the probable expence of clearing the channel of the river *Wear* 176 yards, being the diſtance of the ſituation of the firſt lock, as propoſed by the Gentlemen Coal Viewers, above the ſituation as ſtaked out in November 1760, by JOHN SMEATON.

	£.	s.	d.
To 176 yards of water-tight wearing, at 4*l.* 10*s.* *per* yard, - - - - - - - -	792	0	0
To fixing a temporary croſs dam, at the tail of the *Wear*, and taking the ſame away, - -	10	0	0
To drainage of the water while the ſilt is getting out, ſuppoſing 30 days, at 6*s.* 8*d.* *per* day,	10	0	0
To getting out 1760 cube yards of matter, at 6*d.* - - - - - - - - - -	44	0	0
	856	0	0
To unforeſeen accidents at 10 *per Cent.*	85	12	0
	941	12	0

N. B. The 176 yards of water-tight dam is intended to be executed with oak, in a durable manner, ſo as to remain a fence againſt the ſilt of the river.

General ESTIMATE for compleating the firſt lock and dam, at or near JACKSON's, near *Harraton*, upon the River *Wear*.

	£.	s.	d.	£.	s.	d.
To clearing *Biddick Ford*, and two other ſhoals between that and Mr. *Lambton*'s engine drain,				500	0	0
To wearing and dredging 176 yards from the bottom of the caunch below *Jackſon's Ford*, up to the tail of the lock, as per former eſtimate, —	941	12	0			
To probable expence in the foundation of the lock at *Jackſon's Ford*, ſuperior to that in its firſt intended ſituation, - - - - - - -	258	8	0			
				1200		
To expence of building the lock in its firſt ſituation, - - - -	900	0	0			
To ditto of the dam adjoining, - - - - - - - -	600	0	0			
To cutting the ground drain of the water and temporary dam to both, at leaſt, - - - - - - - - - - - - -	500	0	0			
				2000		
Expence of the navigation from *Briddick Ford* to new bridge,				3700		

N. B. 1ſt. The expence of the machines, ſhops, utenſils, &c. together with the neceſſary materials for beginning the work, will be at leaſt 1000*l.* and if the work goes on no further than the firſt lock, there will be at leaſt 500*l.* loſt by the articles juſt mentioned, which otherwiſe would ſerve for the whole.

THE RIVER CALDER.

Comparative ESTIMATE for carrying on the navigation of the river *Calder*, by means of a long cut from the figure of 3 lock at F, to above *Dewſbury* low ford at H, and of carrying it partly by the river and partly by 3 ſhort cuts as in the general plan.

ESTIMATE for a mile of cut.

	£.	s.	d.
To 14 acres of land at 50 *l.* per acre, - - - - - - - -	700	0	0
To cutting, at a medium, 6 feet deep, 16 feet wide at bottom, and 36 at top, at 3 *d.* per yard cubic, - - - - - - - - - - - - -	381	7	0
To ſodding and batting down the banks, and ſowing them with hay-ſeeds, at 2 *s.* per rood,	41	16	0
To extra work in forming 8 paſſing places, at 5 *l.* each, - - - - -	40	0	0
To 14 quarters of hay-ſeeds, at 7 *s.* per quarter, - - - - - - -	4	18	0
Expence of land, cutting, &c. per mile, - - - - - - -	1168	1	0

ESTIMATE

ESTIMATE for the navigation by the long cut.

	£.	s.	d.
To $2\frac{1}{4}$ miles at 1168 *l.* 1 *s.* per mile, land and cutting, - - - - - -	2628	2	0
To extra work in digging two lock-pits, at 30 *l.* each, - - - - -	60	0	0
To 3 carriage bridges of wood, at 60 *l.* each, - - - - - -	180	0	0
To 3 tunnels for draining, at 10 *l.* each, - - - - - -	30	0	0
To 1 lock building, at 600 *l.* and 1 ditto at 400 *l.* - - - - -	1000	0	0
To 1 low dam at the head of the cut, - - - - - - - -	300	0	0
To extra work in banking near *Millbank Quarry*, and cutting through a rising ground near the *Warren House*, - - - - - - - - -	150	0	0
	4348	2	0
To contingencies on the above articles at 10 *per Cent.* - - - - - -	434	16	0
Total	4782	18	0

ESTIMATE for the navigation as by the general plan.

	£.	s.	d.
To $\frac{7}{8}$ of a mile of cut, at 1168 *l.* per mile, - - - - - - -	1022	0	0
To extra work in digging 3 lock-pits, at 40 *l.* each, - - - - -	120	0	0
To 3 tail-bridges for the locks, at 20 *l.* each, - - - - -	60	0	0
To 1 tunnel for drainage, at 10 *l.* - - - - - - -	10	0	0
To 2 locks building at 600 *l.* and 1 at 400 *l.* - - - - - -	1600	0	0
To 1 dam at 500 *l.* and 1 ditto, at 300 *l.* - - - - - -	800	0	0
To extra expences in crossing the *Calder*, - - - - - - -	100	0	0
To extra expence in removing the new mill cloughs, and setting piles to prevent the boats going over the dam, - - - - - - - -	100	0	0
	3812	0	0
To contingencies on the above articles, at 20 *per Cent.* - - - - -	762	8	0
Total	4574	8	0

The

TETNEY HAVEN NAVIGATION.

The REPORT of JOHN SMEATON, Engineer, concerning the practicability, &c. of a ſcheme of navigation from *Tetney Haven* to *Louth*, in the county of *Lincoln*, from the view taken thereof in Auguſt, 1760, as projected by Mr. JOHN GRUNDY, Engineer.

HAVING carefully examined the ſcheme of navigation propoſed by Mr. JOHN GRUNDY, for making a navigable canal from *Tetney Haven*, to the upper end of *Avingham* out-fen; and from thence to join the river *Lud*, or *Louth* river, between *Ringer's* drain and *Avingham* mill; and from thence, partly by the courſe of the river, but chiefly by a new canal, up to new bridge, at or near the town of *Louth*; and having carefully compared the ſaid ſcheme with the lands through which the aforeſaid navigation is propoſed to paſs, and alſo examined, as well the principal water-courſes, eau-moats, and out-falls, as the havens and communications with the ſea and river *Humber*, which relate to the above ſaid ſcheme, I am of opinion as follows:

1ſt. That *Tetney* haven is the moſt proper out-fall for a navigable canal, as being both ſafeſt and deepeſt, and affording a communication with the inland navigations of *Yorkſhire* and the *Trent*, for flat-bottomed barges, without going to ſea, which, at ſome ſeaſons of the year, would be dangerous or impracticable.

2d. That the courſe of the intended canal, as laid down in Mr. GRUNDY's plan, from Mr. YOUNG's warehouſe, near *Tetney* haven, to its junction with the *Louth* river, between *Ringer's* drain and *Avingham* mill, is the moſt eligible poſition, both for the purpoſe of navigation and drainage, as paſſing in general through the loweſt grounds.

3d. That the reſt of the intended navigable courſe, from the junction of the canal with the river as aforeſaid, to *New Bridge*, near the town of *Louth*, as marked out in the ſaid plan, is alſo very proper, and does not ſeem likely to be attended with any particular prejudice to the owners of the adjacent grounds, more than what is inſeparable from the nature of the undertakings of this kind.

4th. That the owners of the low grounds, that are liable to be affected by the *Tetney* river, will, in particular, receive great benefit from this undertaking; becauſe,

5th. The

5th. The water of *Tetney* river being received into the navigable canal before it meets the fea fluice or lock, as the water of this canal is, by the faid propofed fcheme, to be kept conftantly lower by 1 foot than low water mark of the *Tetney* river, under *Sheep*'s bridge; it follows, that the furface of *Tetney* river will, at its out-fall into this canal, be kept at leaft one foot lower than it could be by placing a fea fluice at or near *Sheep*'s bridge upon the prefent courfe of the river.

6th. I am of opinion, that the carrying the navigation up the *Tetney* river further than *Sheep*'s bridge, will no way contribute to the more effectual drainage of the *Tetney* lands, and will carry the canal confiderably out of its due courfe; but that a navigation for lighters and fmall veffels may be feparately made up the *Tetney* river to *Tetney*, at a fmall expence.

7th. That the furface of the water of the canal, being kept one foot lower than the point of low water at *Sheep*'s bridge, will be lower than the furface of the water in all the drains that it will interfect; and confequently, that the water of thofe drains being turned into the canal, will afford a means of draining thofe lands more effectually, or may occafionally be kept up at their prefent level by fmall fhuttles, or ftops, near the fide of the canal.

8th. Where the paffages for waters from fprings, for watering grounds and other purpofes, are interfected by the intended canal, and are defired to be continued in their prefent courfe, they may be continued by fubterraneous paffages or tunnels, as has already been obferved in Mr. GRUNDY's Report.

9th. That the principal conveyance of fpring water next to *Tetney* river, appears to be that of the North *Coates Fleet*, the furface of which lays higher than the furface of the intended canal, and therefore will difcharge itfelf into the fame; confequently, if there fhould be any objection from *Tetney*, againft fupplying the navigation in dry feafons from their river, fuch fupply may be had from North *Coates Fleet*, or other fources, having communication with the canal upwards.

10th. I am further of opinion, that which ever of thefe ways are thought moft eligible, that the fea lock ought to be provided with ebb-gates, or gates pointed landward, as well as feaward, that the water may be retained in the canal to its due height, and to enable the veffels to pafs at all times when there is depth of water without the fea-lock; it alfo appears to me, that the purpofe of the lock will be as effectually anfwered, by taking in one veffel at a time, as by taking in two.

11th. That

11th. That in caſe the ſeveral pariſhes concerned could be agreeable, that the redundance of one pariſh ſhould contribute to the defects of another, this canal would be the beſt means of performing it; for a part of the water of North *Coates Fleet*, or *Tetney* river, being admitted into the canal, all thoſe grounds contiguous, or which might be brought to communicate with the canal, quite up to *Avingham* out-fen, might, by proper drains, be ſupplied with ſpring water.

12th. That according to the modern practice of building locks, they are capable of being made and preſerved water-tight, wherever this circumſtance is neceſſary.

13th. That according to this ſcheme, no water will be turned away from *Ringer*'s drain, and the eau-moats, except what is neceſſary to fill a part of the firſt lock upon the canal near the upper end of *Avingham* out-fen.

14th. That on the 7th day of Auguſt, 1760, after the drieſt ſeaſon that has been known in the memory of man, I carefully examined the diſcharge of water by the *Louth* river in 24 hours, at *Thorold*'s mill, being the firſt below the new bridge at *Louth*, and compared the ſame with the diſcharge at *Avingham* mill, and found the quantity ſuch as to fill the ſaid firſt lock, near the upper end of *Avingham* out-fen, to the height required for the paſſage of a barge 200 times in 24 hours. So that, even in the drieſt ſeaſons, the quantity of water expended by the navigation will be ſo very inconſiderable, in proportion to what will ſtill remain, that the difference will be quite inſenſible to the occupiers of lands.

15th. That there is a poſſibility that even this inconſiderable loſs of water may be totally prevented in ſcarce water times; but at an expence to the undertaking which ſo inconſiderable a quantity does not ſeem to merit.

16th. That the courſe of the river from the place of junction of the canal therewith to the town of *Louth*, being narrow, crooked, and generally ſhallow, with level meadows on one or both ſides, and ſcarcely any part of it in a navigable ſtate; I apprehend it will be more eligible and leſs expence to dig a new canal, with locks upon the ſame, at proper diſtances, than to purſue the old courſe of the river; and that the ſcheme above referred to, is very proper for this purpoſe.

17th. That the riſe of the river, from the place of junction of the canal with the river, as aforeſaid, to *Keddington* old mill, is very gentle, being in length about $2\frac{3}{4}$ miles,

and

and riſe about 24 feet, according to Mr. GRUNDY's ſurvey; from thence to a meadow a little below the leather mill the aſcent is more ſudden, being $11\frac{1}{2}$ feet in three quarters of a mile; and from thence to the new bridge at *Louth* ſtill more, being about 21 feet in the ſame ſpace.

18th. I am therefore of opinion, that the diſtance of three quarters of a mile from the leather mill, to the new bridge at *Louth*, will be, in proportion to the diſtance, the moſt expenſive part of the undertaking; but that a conſiderable ſum will be ſaved by terminating the navigation at *Kiddington* old mill, to which place it may be brought on very moderate terms.

Auſthorpe, July 14, 1761. J. SMEATON.

GENERAL ESTIMATE of the expence of making a navigation from *Tetney Haven* to *Louth*, according to Mr. GRUNDY's plan.

	For barges with canals wide enough for two to paſs in all places.	For barges with canals for one, with paſſing places.	For lighters drawing 2 feet water.
	£.	£.	£.
From *Tetney Haven* to the new bridge at *Louth*,	15,590	13,686	10,884
From *Tetney Haven* to the meadow below the leather mill, - - - - - -	12,968	11,241	8,931
From *Tetney Haven* to *Keddington* old mill,	11,098	9,481	7,589
From *Tetney Haven* to the top of *Avingham* out-fen, - - - - - - -	7,853	6,566	5,312

N. B. In the above eſtimate the expence of procuring an act of parliament is not included. The marſh land is eſtimated at 10*l.* and the meadow at 20*l.* per acre; the ground covered is reckoned at half value, or, what is the ſame thing, at half quantity: the quantities to be purchaſed are as under, ſo that whatever alteration there may be in the price now ſuppoſed, the difference may be applied without affecting the other articles.

	2 barge canal.	1 barge canal	canal for lighters.
	acres.	acres.	acres.
Marſh lands,	57	$45\frac{1}{2}$	40
Meadow land,	$32\frac{1}{2}$	26	$22\frac{1}{4}$
Total acres,	$89\frac{1}{2}$	$71\frac{1}{2}$	$62\frac{1}{4}$

Auſthorpe, July 14, 1761. J. SMEATON.

The

RIVER WITHAM.

The **REPORT** of Meſſrs. JOHN GRUNDY, LANGLEY EDWARDS, and JOHN SMEATON, Engineers, concerning the preſent ruinous ſtate and condition of the river *Witham*, and the navigation thereof, from the city of *Lincoln*, through *Boſton*, to it's outfall into the ſea; and of the fen lands on both ſides the ſaid river: together with propoſals and ſchemes for reſtoring, improving, and preſerving the ſaid river and navigation, and alſo for effecting the drainage of the ſaid fen lands: to which is annexed a plan, and proper eſtimates of the expences in performing the ſeveral works recommended for thoſe purpoſes.

INTRODUCTION.

THE river *Witham*, from *Lincoln* to *Boſton*, falls in a crooked courſe through the low grounds of the ſeveral lordſhips following, on the ſouth ſide thereof, viz. *Lincoln*, *Canwick*, *Waſhinborough*, *Branſton*, *Potter-Hanworth*, *Nocton*, *Dunſton*, *Metheringham*, *Blankney*, *Marton*, *Timberland*, *Timberland-Thorpe*, *Walcot*, *Billinghay*, *Billinghay-Dales*, and *Dogdike*, to *Chappel Hill*; and on the north ſide through the low grounds of *Monks*, *Greetwell*, *Willingham*, *Fiſkerton*, *Barlings*, *Stainfield*, *Bardney*, *Southrey*, *Tupholm*, *Bucknall*, *Horſington*, *Stixwold*, *Swineſike*, *Woodhall*, *Thornton*, *Kirkſtead*, *Tatterſhall*, and *Coningsby*: and from the ſaid *Chappel Hill* it runs, in a very crooked and meandring courſe, betwixt the large and extenſive fens called *Holland Fen* on the ſouth, and *Wildmore* and *Weſt Fens* on the north, to *Room*'s *Hall*, and from thence, through ſome incloſures, to *Boſton*, and from *Boſton*, through the *High Marſhes*, into the great bay called *Metaris Eſtuarium*. The diſtance from *Lincoln* to *Boſton*, by the old courſe of this river, is about 43 miles.

This river has formerly been a very good navigation from it's outfall at the *Scalp* to *Boſton*, (which is about 4 miles) ſufficiently capacious and deep to navigate large ſhips into the town, and from thence to convey barges, keels, and other veſſels, to *Lincoln*, almoſt at all times in the year; and a very extenſive and advantageous branch of commerce has, till of late years, been carried on by the ſaid river, to the great benefit and advantage, not only of the city of *Lincoln* and town of *Boſton*, but alſo of the ſeveral towns and villages adjoining upon, and contiguous to it, through an extent of country for many miles in length and breadth.

It

It was alſo, when in the aforeſaid ſtate and condition, the mother river and outfall for the drainage, not only of the low grounds and fens aforeſaid, but alſo of the low grounds of *North Kyme Fen*, *South Kyme Fen*, *Hart*'s *Grounds*, *Great* and *Little Beats*, *Rakes*, *Heckington Fen*, *Lady Frazer*'s 600 *acres*, *Ewerby*, *Howel*, *Aſgarby*, *Great* and *Little Hales*, *Brothertoft*, *Anwick*, *Ruſkington*, *Dorrington*, *Digby*, *Marcham*, *Hundle-Houſe*, *Reveſby*, *Middleham*, *Moor-Houſe*, *Meer Booth*, *Hermitage*, *Newholme*, *Weſt-Houſe*, *Langrike*, *Frith Bank*, *Langworth*, *Swinecote*, *Stickford*, and *Stickney*; and alſo of many other low grounds and fens lying more diſtant and remote therefrom, (but having their outfalls for drainage into it) containing in the whole, by eſtimation, upwards of 100,000 acres.

This once ſo flouriſhing river and country have, for many years laſt paſt, been falling into decay, by the banks of the ſaid river being ſuffered to become ruinous, and incapable of ſuſtaining and confining the water in times of high country floods, ſo that thoſe flood waters, which were neceſſary and uſed heretofore, by their velocity and weight, to cleanſe out the ſand and ſediment brought up by the tides, have been, and now are, ſuffered to run out of their ancient and natural courſe, and expand over the adjoining fens and low grounds, whereby thoſe ſands, for want of a reflowing power of adequate force to carry them back, have now ſo much choaked up the haven from *Boſton* to the ſea, that for ſeveral years laſt paſt the navigation thereof has been loſt for ſhipping, and it is now become even difficult for barges of about 30 tons burthen to get up to the town in neap tides. And for ſeveral miles above the town of *Boſton* the ſaid river is totally loſt; inſomuch that it's bottom is, in many parts, ſome feet higher than the adjoining low grounds, and the ſcite thereof converted into grazing and farming purpoſes.

This miſchievous effect has not only been deſtructive to the navigation of that river, but alſo to the drainage of the aforeſaid vaſt tracts of fens and low grounds, by reaſon that many of the mouths of the inward drains, dikes, and ſewers, which ſhould have their outfalls into this river, are totally landed up, and loſt, and have not run at all for many years into it; and the few that have their outfalls ſo low as *Boſton*, and below it, are neverthleleſs, in all dry ſeaſons, ſo much choaked up and obſtructed, that the ſaid fens and low grounds muſt be, in ſome parts, conſiderably under water, before they can have vent through their outfalls into the ſaid river or haven, whereby the flood-waters lye ſo long ſtagnant thereupon, as to deſtroy the herbage thereof, and render them not only uſeleſs and unprofitable, but alſo extremely noxious and unwholeſome to the adjacent inhabitants.

 To

To find out proper and neceſſary expedients to improve this river and fens, ſurveys and levels were taken, ſome years ago, from *Wiberton Roads* to *Lincoln*, not only along the courſe of the ſaid river, but alſo on the adjoining fens and low grounds, to compare their different ſurfaces, both with reſpect to the ſaid river and their outfalls to ſea; in conſequence of which a ſcheme was formed, and publiſhed in the year 1744, by Meſſrs. GRUNDYS, Engineers, recommending ſuch expedients as, to them at that time, appeared proper for effecting the above deſirable purpoſes; upon which, ſeveral meetings have from time to time been held, to conſider this and other ſchemes, and many clauſes were prepared for a bill, particularly at a meeting held at *Lincoln*, in November, 1753, and others ſubſequent thereto.

In the year 1760 Mr. LANGLEY EDWARDS was employed to make views of the premiſes in queſtion, and ſince then Mr. GRUNDY, the ſon, has reſurveyed the river and fens, and both have made their ſeveral reports thereupon; which ſaid ſurveys, levels, reſolutions, and reports being duly conſidered, and a freſh view taken of the river and fens in October, 1761, by Meſſrs. GRUNDY and EDWARDS, in conjunction with Mr. JOHN SMEATON, Engineer, we, the ſaid JOHN GRUNDY, LANGLEY EDWARDS, and JOHN SMEATON, are jointly of opinion as follows, viz.

REPORT.

IN the firſt place it appears to us, that from the great tendency of this river to ſilt, and the great advance the ſame has made in the ſpace of 20 years, that in all human probability within the compaſs of a few years more, not only the outfalls of the preſent effective drains near *Boſton* will be totally loſt, but the whole river landed up, unleſs ſufficient meaſures are ſpeedily taken to prevent it; and the moſt eligible means for ſo doing, we conceive, will be to make and preſerve a mother river, of ſufficient depth and capacity, to effect a general drainage of the ſeveral fens and low grounds aforeſaid, and alſo to reſtore this loſt navigation, from the ſea through *Boſton* to *Lincoln*, and into the *Brayford Meer*, (which has a navigable communication through the *Foſſdike* with the river *Trent*) upon the following principles, and by the following methods, viz.

1ſt. That

1ſt. That the new propoſed river be made in the ſhorteſt direction that can be, conſiſtent with the loweſt ſurface of the country, conſidered in a medium proportion, and moſt convenient for receiving the waters thereof.

2d. That its dimenſions be ſuch as to be capable of receiving and diſcharging, not only all the upland waters, but alſo all thoſe of the ſeveral branch rivers and drains that fall into it.

3d. That its banks be made of ſufficient ſtrength and height to confine the flood waters within them, and to force them down to ſea, without overflowing the adjoining ſens and low grounds.

4th. That its bottom be made with a regular declivity from *Lincoln* to the ſea; which, according to the levels, will be at a medium near $5\frac{1}{2}$ inches per mile.

5th. To collect all the living waters into this new river that can be obtained, by ſcouring out and imbanking all ſide rivers, rivulets, and brooks that bring down ſuch living waters out of the high country into it, in order to obtain a reflowing force that ſhall be capable of driving out ſuch matter as is left by the tides, by which means only the outfall below can be preſerved open and clean.

6th. To ſtop the tides from flowing at all into this new river, that its depth and dimenſions may be preſerved.

7th. That this work ſhall be ſo conſtructed, that navigation may be carried thereon ſo, as in no wiſe to interfere with, or prejudice the drainage.

8th. That the neceſſary works be conſtructed to retain the freſh water, to be made uſe of as occaſion ſhall require, for the well watering the ſaid fens and low grounds in dry ſeaſons for the uſe of cattle, &c.

And laſtly. That no ſalt water be admitted into the mother river, or drains, above *Boſton*, by means of the propoſed navigation.

The

The SCHEME for the Drainage.

1ſt TO erect a ſea ſluice, for ſtemming the tides between *Lodowicks Gowt* and *Boſton Bridge*; and we recommend a piece of ground, commonly called *Harriſon*'s four acres, at (A) (ſee the plan for that purpoſe), the floor whereof to lie level with low water mark at *Wibberton Roads*, and its neat capacity or clear waterway to be 50 feet, with three pair of pointing doors to the ſeaward, to ſhut with the flow of the tides, and drop or draw-doors on the land ſide, to be ſhut occaſionally, to retain freſh waters in dry ſeaſons; the top of theſe draw-doors to be gaged to ſuch a height, as to retain the water of the river, not higher, at ordinary ſeaſons, than 2 feet below the ſurface of the loweſt lands that drain therein.

2d. To make a new cut from this ſluice to, or near, *Anthony's Gowt*, (A B) in as ſtraight a direction as the nature of the ground will admit of; 80 feet broad at the top, 50 feet broad at the bottom, and 10 feet deep: and from the ſaid place at, or near *Anthony's Gowt*, to make a new cut (in as ſtrait a direction, alſo, as the nature of the ground will admit of) through *Wildmore Fen* to *Chapel Hill* (C), at a medium, 66 feet wide at top, 50 feet wide at bottom, and 8 feet deep, The earth coming out of this new river to be diſpoſed of in forming banks, which are propoſed to be ſet 40 feet diſtance from the Brink of the river.

3d. The river, from the upper end of this new cut, at *Chapel Hill*, to *Lincoln*, is propoſed to be continued in its preſent courſe; but the ſhallow parts thereof to be ſcoured out and deepened, where neceſſary, ſo as to be every where of the following dimenſions at a medium, viz.

For three miles and a half above *Chapel Hill*, 60 feet broad at the top, 40 feet broad at the bottom, and 5½ feet deep below the preſent bottom. From thence to *Waſhingborough* lordſhip, above *Branſton Dyke*, (being about 12½ miles) this river (having the waters of ſeveral rivulets and brooks to receive within thoſe limits) ſhould be 40 feet wide at the top, 30 feet wide at the bottom, and 2 feet deeper than its preſent bottom, at a medium. From hence to *Stamp End*, in *Lincoln*, (being about 10 miles) to deepen the ſhoals in the old river, ſo as to be 30 feet broad at the top, 24 feet broad at the bottom, and 2½ feet deeper than they now are on an average.

4th. The

4th. To make and erect one waggon bridge at (D), and two horſe bridges, (E and F), with neceſſary gates and fences for continuing the roadway and other communications, and for dividing the *Wildmore* and *Weſt Fens* from *Holland Fen.*

5th. To ſcour out and imbank *Kyme Eau*, from *Dampford* ſluice to the river, or ſo much further as may be found neceſſary, ſo that its banks may be 30 feet ſeat, 6 feet at the top, and 6 feet high.

6th. To ſcour out *Tatterſhall Bane*, from the mouth thereof to *Dickinſon*'s engine, and repair the banks thereof, ſo as to be 30 feet ſeat, 6 feet at the top, and 6 feet high.

7th. To ſcour out and imbank *Billinghay Skirth*, from the *Witham* to *Billinghay Town*, ſo that its banks may be of the ſame dimenſions as the former; and alſo to ſcour out and imbank the *Skirth*, from *Billinghay Town* to *Kyme* cauſeway bridges, ſo as to be of proportionable dimenſions, for draining the low grounds above the ſaid cauſeway.

8th. To ſcour out *Barling's Eau*, from the river to *Barling's Abbey*, and repair the banks thereof, ſo as to be 15 feet ſeat, 5 feet at the top, and 5 feet high; and alſo to dike out and embank *Stainfield Beck* proportionable to the former.

9th. To ſcour out and imbank *Dun's Dike*, from the river *Witham* to the *Carr Dike*, (or inſtead thereof to reinſtate the *Car Dike*, and turn its waters therein,) ſo that its banks may be 15 feet ſeat, 5 feet at the top, and 5 feet high.

10th. To ſcour out and imbank *Nocton Dike* and *Hare's Head Drain*, from the river to the *Carr Dike*, ſo that its banks may be 12 feet ſeat, 4 feet at the top, and 4 feet high.

11th. To ſcour out and imbank *Waſhingborough Beck*, from the river to the *Carr Dike*, of the ſame dimenſions as the laſt.

12th. To ſcour out *Tupham Dike*, *Bardney* or *Tilehouſe Beck*, *Southery Eau*, and *Stixwold Beck*, and imbank the ſame proportionate to the flood waters they bring down.

N. B. *Lodowick's Gowt* will be wanted for diſcharging the river waters during the execution of the work.

And, for the more certain drainage of *Wildmore* and *Weſt Fens*, a new cut and ſluice, to ſupply the place of *Anthony's Gowt*, be made and erected by the ſide of the ſaid new

propoſed

propofed river, and that the floor thereof be laid as low as the bottom of the faid river.

When the works above recommended are put in practice, and have had the neceffary time to produce their effects upon the out-fall, we are of opinion, that the furface of the water in the New River will be capable of running at leaft 4 feet lower at ordinary feafons, than at prefent it can do, and confequently that not only all the lands lying immediately thereupon will be put into a condition of effectual drainage, but alfo fuch parifhes which at prefent drain by engines into *Holland Fen,* or into the feveral fewers bordering thereupon, and will likewife be of fervice in affording a more ready difcharge of the downfall waters from the lands lying ftill further from their out-fall.

The SCHEME for Navigation, viz.

1ft. TO erect a lock with two pair of doors, pointing to the landward, for the purpofes of navigation, and one pair of doors pointing to feaward, to keep out the tides.

2d. Upon mature confideration, and comparing the advantages and utility with the increafe of expence, we are of opinion, that locks are greatly preferable to ftaunches, though the expence of the former will be confiderably more than the latter. We therefore propofe to erect three locks in proper places, by the fide of the mother river, betwixt the fea fluice and the city of *Lincoln,* to retain the waters therein for the purpofes of navigation in dry feafons (which at the fame time will be fubfervient to the watering of cattle) and one above *Sincil dike* in *Lincoln,* to communicate the navigation of the *Witham* with the *Foffdike*; but that the faid locks may not be prejudicial to drainage in wet feafons, the three former are to be fo limited in their height, that they fhall not retain the waters of the main river any higher than within two feet of the natural furface of the loweft grounds above them; and the weirs or waftes appertaining thereto, fhall be compofed of flood gates, which together fhall be of the fame capacity with the river, in the refpective parts where fuch locks are to be erected, and the latter (propofed to be erected above *Sincil dike)* fhall be limited to fuch height, as not to pen the waters higher than the prefent natural ftaunch at *Brayford Head,* and that a wafte or weir be erected at the upper mouth of *Sincil dike* at G, at the fame level with this lock, fo that no prejudice may be

be occasioned thereby to the present state of the *Fossdike* navigation, or to the low grounds above *Lincoln*.

3d. For the careful and safe management of the locks, and that the waste gates may be at all times opened upon the approach of any flood, or when the river is overcharged with water, a dwelling house is proposed to be built against each lock, and a watchman to be fixed in each to take care thereof.

4th. To deepen the bed of the river, betwixt staunch and staunch, sufficient for the purpose of navigation, which at a medium will be about 13 inches, which done will make 3 feet navigation.

5th. To make proper halingways for men and horses on the banks and forelands of the said river, and that no damage may be done thereby, proper gates, bridges, styles and fences be put down betwixt property and property, through which the said halingways may lead.

An ESTIMATE of the expences that will probably attend the execution of the foregoing proposed works, viz.

The SCHEME for drainage.

	£.	s.	d.
The sea sluice near *Boston* to be laid level with the low water mark at *Wibberton* roads (which is 3 feet 1 inch and 9 parts lower than *Ledowick's Gowt*) with a timber floor, supported by dovetail and bearing piles, braces and tyes, with a superstructure of brick and stone, with three arches to contain 50 feet neat waterway, the sea and land doors of oak, &c. &c.	4000	0	0
To making the new cut from this sluice, to or near *Anthony's Gowt* (being 760 roods at 20 feet to the rood) so as to be 80 feet broad at the top, 50 feet broad at the bottom, and 10 feet deep at a medium, will contain 32½ floors in a rood, and for the whole length 24,700 floors, which, as the earth is to be barrowed to the distance of 40 feet from the brink of the river on each side, and laid in bank fashion, and on account of the great depth of the said cut, will cost about 5s. per floor (or 400 cubical feet) and comes to - -	6175	0	0
The inclosed land to be cut through will contain about 6 acres, which, at 30*l.* per acre, comes to - - - - - - - -	180	0	0
The forelands and cover of the banks will contain about 13½ acres, which, at 15*l.* per acre, is	202	10	0
The commons to be cut through will contain 22 acres, which, at 10*l.* per acre, is -	220	0	0
The forelands and cover will be 49¼ acres, which, at 5*l.* per acre, is - -	246	5	0
Carried over	11023	15	0

	£.	s.	d.
Brought over	11023	15	0
To taking away the old banks, and cutting acrofs the old river - - -	200	0	0
To erecting a new fluice at *Anthony's Gowt*, and making the communication cut -	600	0	0
To making a new cut acrofs *Wildmore Fen*, from or near *Anthony's Gowt*, to *Chappel Hill* (being 1848 roods) 66 feet broad at the top, 50 feet broad at the bottom, and 8 feet deep on an average, will contain 232 floors in a rood, and for the whole length 42873,6 floors, which, at 4*s.* per floor, comes to - - - - -	8574	14	5
The land to be cut through will contain 56 acres of common fen land, which, at 10*l.* per acre, comes to - - - - - -	560	0	0
The forelands and cover of the banks will contain 136 acres, which, at 5*l.* per acre, comes to	680	0	0
To fcouring out three miles and a half above *Chappel Hill*, fo as to be 60 feet broad at the top, 40 feet broad at the bottom, and 5½ feet deep below the prefent bed, will contain 13¾ floors in a rood, and for the whole length (which is 924 roods) 12705 floors, which, at 4*s.* per floor, comes to - - - - - - -	2541	0	0
To diking out the old river where neceffary, and imbanking the fame from thence to *Lincoln*, being in length 22½ miles, which, being eftimated at 150*l.* per mile at a medium, comes to - - - - - - -	3375	0	0
To erecting a waggon bridge over the new river, in the road from *Langrike Ferry* to *Horncaftle*, and two other bridges for communication of the cattle for the ufe of the commons, and to making good the fencing betwixt *Wildmore* and *Weft Fens* and *Holland Fen*, about	1000	0	0
To repairing *Lodowick's Gowt*, and making proper cuts to difcharge the water during the work, leaking out water in the reaches, &c. - - - - - -	1400	0	0
To materials of barrows and planks, treffells, gang ladders, engines, and other utenfils, &c. and carriage of them to the work - - - - -	1200	0	0
To fcour out and imbank *Kyme Eau*, from *Dampford Sluice* to the river, and repairing the banks thereof according to the fcheme - - - -	1000	0	0
To ditto of *Tatterfhall Bane*, of the fame dimenfions as the laft, from the *Witham* to *Dickinfon's Mill* - - - - - - -	300	0	0
To ditto of *Billinghay Skirths*, from the *Witham* to *Billinghay Town*, and from thence to *Kyme Caufeway Bridges*, as per fcheme - - - - - -	800	0	0
To ditto at *Barling's Eau* and *Stainfield Beck*, and repairing the banks thereof to the dimenfions mentioned in the fcheme - - - - -	500	0	0
To fcouring out and imbanking *Dunt Dike* (or the *Carr Dike*) as directed in the fcheme -	400	0	0
To ditto of *Nocton Dike* - - - - - -	275	0	0
To ditto of *Wafhingborough Beck* - - - - -	60	0	0
To ditto of *Tupham Dike*, *Bardney* or *Tilehouft Beck*, *Southery Eau*, and *Stixwold Beck* -	360	0	0
To unforefeen and incidental contingencies, furpervifing, and officers to attend this work -	3000	0	0
Total for the works of general drainage	37849	9	5

An

An ESTIMATE of ſuch works as concern navigation only, viz.

	£.	s.	d.
To making and erecting the ſide lock or penn ſluice, as propoſed in the ſcheme -	1200	0	0
To building 3 locks with proper waſtes and flood gates, as per ſcheme, between *Chappel Hill* and *Lincoln* - - - - - - - -	2000	0	0
To three watch-houſes, and purchaſing the ground - - - -	150	0	0
To erecting the propoſed lock in *Lincoln* above *Sincil Dike*, as per ſcheme - -	400	0	0
There will alſo be a neceſſity to deepen the bed of the mother river for the purpoſes of navigation, over and above what is required for draining, upon an average 13 inches, from *Chappel Hill* to *Lincoln*, which is 26½ miles, and will coſt about 80*l.* per mile, and comes to	2120	0	0
And for deepening the paſſage from the lock above *Sincil Dike*, through the high bridge, into *Brayford Meer* - - - - - - -	200	0	0
To materials of barrows and planks, engines, gang ladders, treſſells, &c. for this work -	500	0	0
To unforeſeen contingencies and ſuperviſing the works - - - - -	800	0	0
Total for navigation - - - - - - -	7370	0	0

JOHN GRUNDY.
LANGLEY EDWARDS.
J. SMEATON.

Sleaford, November 23, 1761.

RIVER CHELMER NAVIGATION.

The REPORT of JOHN SMEATON, Engineer, concerning the practicability of making the river *Chelmer* navigable from *Malden* to *Chelmsford*, in the county of *Essex*, from a view thereof taken the 28th and 29th of May, 1762; from whence it appears as follows:

1st. THAT the river above *Chelmsford* bridge, which runs alongside the town for about a furlong, is sufficiently deep and capacious for navigation, and so continues below the said bridge, till within about half a furlong of *Mouseholm Mill*, where it seems too shallow. This tract of the river appears convenient for wharfs and landing-places; but in case it should be thought proper to carry the navigation above bridge, one of the arches must be taken down and rebuilt, none of them being of sufficient capacity for the craft to pass. There is also ample convenience for making wharfs, either by pursuing the *Chelmer*, or by cuts through the level meadows on the north-east side of the town.

2d. *Mouseholm Mill* may be passed by a cut and a lock on either side, but I apprehend with most convenience on the north side, the cut to fall into the river about half a furlong below the mill, where the river makes a remarkable elbow to the north. This will avoid the shoals below the mill; the water from the waste gates of the *Chelmer* near the town to fall into this new cut below the lock, and be conveyed thereby to the point already remarked.

3d. From the point above remarked, the river continues good till about half a furlong above *Harrington's Mill*, where there are further obstructions, which continue below that mill very near to *Sanford Mill*, and below *Sanford Mill* the river is remarkably narrow, winding, and obstructed with weeds and beds of sand and gravel for above a mile, and grows very little better till opposite Captain *Honeden's* house; after that it is still winding, and much obstructed with weeds, &c. till a quarter of a mile above *Boreham Mill*; but below the paper mill the river is again shallow, narrow, and obstructed, so as to be in no respect fit for navigation, till a little below *Langford Church* (which stands within 15 yards of the river); from hence the river is spacious and good down to *How Mill*. The river at *How Mill*, and from half a furlong above, verges so close to the high land, that no cut is practicable there on the south side of the river; but on the north side there is an extent of flat meadows.

4th. Now

4th. Now confidering the great difficulties and obftructions that occur in the river, between *Harrington's Mill* and *Langford Church*, a fpace near upon 7 miles, and that no part worthy of confideration appears at prefent in a navigable ftate, except the fpace aforefaid, about three quarters of a mile between *Boreham* Bridges and Paper-mill; and confidering that the extra charges in getting into and out of the river, in order to occupy this fpace, would nearly be equivalent to the expence of continuing a cut by the fame, I am therefore of opinion, that the moft cheap, as well as effectual method of making a navigation, would be to defert the river at an elbow about half a furlong above *Harrington's Mill*, veering away towards the fouth-eaft till it meets the high ground, and then purfuing the fkirts of the rifing ground, that is, as much as poffible the confines between the upland and the meadows, which is in general land of the leaft value. A cut may be continued with very little interruption on the fouth fide of the river from the point aforefaid, juft above *Harrington's Mill*, to another point a little below *Langford Church*, making locks at proper places, fo as to fuit the declivity of the ground.

5th. The courfe of the river below *How Mill* becomes again narrow, fhallow, winding, and obftructed with weeds for a fpace of 2 miles, and is not fufficient for navigation till about half a mile above *Bealy Mill*, and from thence it holds good to *Bealy Mill*.

6th. The fpring tides flow about 5 feet at the tail of *Baily Mill*, fo that lighters come up thither at thofe tides to take away their goods. At common neap tides there is little or no flux here. The diftance from thence to *Malden*, by the courfe of the river, is fomewhat lefs than a mile; and the water runs upon a gentle declivity at low water, from thofe mills to *Malden Bridge*. The common fpring tides flow 8 feet, or upwards, at *Malden Bridge*, and the neap tides about 3 feet; but the neap tides fometimes fall fo fhort, even here, as not to rife above 1 foot. Thefe obfervations, concerning the tides, were taken partly from my own obfervations of the tide marks, and partly from the beft information I could procure upon the place.

7th. Confidering the natural courfe of the river from *How Mill* to *Malden Bridge*, as aforefaid, I am of opinion, that the cheapeft way to make the moft perfect navigation the circumftance will admit of, is to take a cut out of *How Millpond*, with a lock thereupon, leaving *How Mill* to the fouth, and either keeping wholly to the north of the river, or otherwife interfecting the river twice within three quarters of a mile below *How Mill*, to pafs by *Bealy Mill*, without coming into its pond at all, leaving that mill on the fouth,

fouth, and keeping down the meadows to drop into the river a little above *Malden Bridge*, on the north fide of the river.

'Tis true that the cut might ultimately drop into the river juft below *Bealy Mill*, which would fave about three quarters of a mile of cut; but as there is, according to the above information, at a medium, near 3 feet more tide at *Malden Bridge* than at *Bealy Mill*, the difference would be, that in one cafe a communication between *Chelmsford* and *Malden* would feldom be interrupted, and in the other cafe never open but at fpring tides.

Upon the whole, I am of opinion, that though there is a poffibility to make the river *Chelmer* navigable by its natural courfe, yet there is fo fmall a proportion thereof that is at prefent adapted to navigation, that it will prove the leaft expence, and by far the moft eligible method, to perform the fame chiefly by canals, in the manner above fpecified, which canals being fupplied with fufficient bridges for the public roads, carriage and other bridges for communication between private properties, under-ground tunnels and paffages for brooks and water-courfes, and back drains for carrying off any foakage that may happen where the water is confined by banks above foil; I fay, things being thus provided for, the private properties of land will be no otherwife affected, than by fo much diminution as fhall be neceffary for the works themfelves. And having made obfervations on the quantity of water current in the *Chelmer* at the time of this view, I am of opinion, that one 60th part thereof will be fufficient for paffing one veffel per day, and confequently that the mills will not be fenfibly affected by lofs of water, at the fame time they are moft of them capable of being improved to near double their prefent produce. Laftly, having confidered the above particulars, and made an eftimate of the expence, fo far as I can judge without a more particular and accurate furvey of the whole, fuppofing the length not to exceed 13 miles of new canal, the whole fall not exceeding 67 feet, and the value of the land not exceeding 60*l.* per acre, 3 feet navigable water, and the whole performed fo as not to require above 1*l. per Cent. per Ann.* of the firft expence to keep the fame in repair for ever, may be done for 16697*l.*

Aufthorpe, 21 June, 1762. J. SMEATON.

The

POTTERICK CARR.

The REPORT of JOHN SMEATON, Engineer, concerning the drainage of *Potterick Carr*, near *Doncaſter*, in the county of *York*; from a view and levels taken in July, 1762.

POTTERICK CARR is a fenny piece of ground, containing, as appears by an old ſurvey of *Saxton*'s, about 2300 acres: in its preſent ſtate, no brook or ſpring of any account diſcharges itſelf thereupon, ſo that it is affected only by the down-fall waters which fall immediately thereon, and from the higher grounds which border upon the ſame. Theſe down-fall waters, however, on account of the natural flatneſs of its ſurface, the imperfection of its preſent drains, and the want of a ſufficient out-fall to diſcharge them, generally overflow the whole, or greateſt part thereof, during the winter ſeaſon; which waters are partly diſcharged by the drains, and partly evaporated by the ſun, ſo as in dry ſummers to be tolerably dry, as was the caſe when the preſent view thereof was taken.

This carr is bounded on the S. E. by the river *Torne*, which runs conſiderably above the ſurface of the carr; but is banked off, ſo as ſeldom to overflow the ſame; the whole drainage of the carr is therefore performed by a ſeparate drain, called *Steeking Dyke*, which falls into the *Torne*, near *Roſington Bridge*, about half a mile below the loweſt point of the carr.

On the oppoſite ſide of the river *Torne*, extending the whole ſpace that river borders upon *Potterick Carr*, and ſomewhat higher, is *Holmes Carr*, conſiſting of ſome hundred acres, which are alſo banked off from the *Torne*, ſo as to be ſeldom overflowed thereby. The ſurface of this carr, for the greateſt part, lays alſo below the ſurface of the contiguous river, yet ſomewhat higher than *Potterick*. This carr is however ſubject to the ſame inconveniencies as *Potterick Carr*; for in this are ſcarcely any drains at all, ſo that the down-fall water is obliged to find its way over the ſurface, by a natural declivity, into the river *Torne*.

Part of the ſouth ſide of *Potterick Carr* is bounded by *Crookhill* bank and drain, which prevents the ſpring and down-fall waters from *Loverſal* from entering the carr, and which are carried by the ſaid drain into the *Torne*, at a place called *Crookhill Nook*.

On the ſouth ſide of *Crookhill* bank and drain, and bordering on the river *Torne*, is a large tract of low land, called *Wadworth Carr*, the ſurface whereof lays conſiderably higher

higher than *Potterick Carr*; but as the out-fall of its drainage is into the *Torne* at *Crookhill Nook*, and the surface of the *Torne* there being some feet higher than at *Rosington Bridge*, the drainage of *Wadworth Carr* is in much the same condition as that of *Potterick Carr*; and this is said to be the case with a large tract of country bordering upon *Wadworth Carr*, and extending upwards as far as *Tickhill*: I therefore propose to consider the drainage of *Potterick Carr* in a two-fold light: first, as it is, or may be, connected with the drainage and improvement of this large tract of country; and secondly, as to what concerns *Potterick Carr* alone.

On this account, I viewed the whole river *Torne*, from *Rosington Bridge*, to the out-fall of its waters at *Austhorpe* sluice, which is a space that, following the banks thereof, cannot be less than 22 miles; I also pursued the drains leading to *Austhorpe* sluice, quite across, by way of the old *Dunn*, to *Thorn* sluice, and from thence into the present river *Dunn*. I also carried a level from the river *Dunn*, at the crimpsal above *Doncaster*, cross the little moor and the high ground, whereon is the road leading from *Doncaster* to *Loversal*, at *Balby* out-gang gate; thence cross *Potterick Carr*, by way of the old *Eau* (a natural lake therein), down to its lowest point, called *Toad Holes*; thence, by way of *Stecking Dyke*, to *Rosington Bridge*, and down to the beginning of the participants drain, about 5 miles below *Rosington Bridge*, and about 300 yards above *Gatewood Bridge*. I likewise carried a level from the surface of the *Torne*, at *Crookhill Nook*, to *Rosington Bridge*, comparing the same with the surface of *Potterick*, *Wadworth*, and *Holmes Carrs*; and, lastly, a level from the surface of the water of the old *Eau*, to the top of the lowest grounds of the bridge on *Cantley Common*, near *Doncaster* horse course. From which views and levels I would lay down the following facts and observations.

LEVELS from the *Dunn* at the *Crimpsal* above *Doncaster*, to the *Participants Drain*, near *Gatewood Bridge*.

	F.	I.
1st. Mean surface of the *Crimpsal* above the water of the *Dunn*, opposite *Newton*, 27 July, 1762, - - - - - - - - - -	8	0
2d. Mean surface of the grounds lying between the *Crimpsal* and the *Little Moor*, above the said point of the *Dunn's* surface, - - - - - - -	17	0
3d. Mean surface of the *Little Moor*, above the *Dunn*, - - - - -	14	0
4th. The causeway in the road from *Doncaster* to *Loversal*, opposite *Balby* Out-gang gate, above the surface of the *Dunn*, - - - - - - -	39	7¾
5th. The mean surface of *Potterick Carr*, about 100 yards within the border thereof, near the Out-gang gate, above the said surface of the *Dunn*, - - - - -	5	2¼
6th. The lowest part of the *Carr's* surface, near the *Division Dyke*, on the west side of the dyke, and on *Loversal* side of the *Carr*, is nearly level with the surface at the former station, and therefore above the *Dunn*, - - - - - - -	5	2¼

7th. The

	F.	I.
7th. The surface of the water in the old *Eau*, which may be esteemed the sink of the *Carr* above the *Dunn*'s surface, - - - - - - - -	4	4
8th. The surface of the *Carr* at the *Toad Holes*, near the old engine, above the surface of the old *Eau*, - - - - - - - - -	1	2
9th. The surface of the river *Torne*, just below *Rosington Bridge*, below the old *Eau*, including a fall at the bridge made by the carriages driving through the water, amounting to 2½ inches,	0	10½
10th. The surface of the river *Torne*, at the bottom of the strait cut or river, extending about a furlong below *Rosington Bridge*, below the surface of the old *Eau*, - - -	1	9
11th. The surface of the river *Torne*, opposite a birch tree at the side of the meadow on the south side of the river, about 5 furlongs below *Rosington Bridge* below the old *Eau*, -	4	0
12th. The surface of the river *Torne*, just above the houses at *Oakly Dam*, above the old *Eau*,	4	8¼
13th. The surface of the river *Torne* at the foot bridge, about 100 yards below the road at *Oakly Dam*, below the surface of the old *Eau* - - - - - -	6	0
14th. The surface of the river *Torne*, at the entry of the *Participants Drain*, about 5 miles below *Rosington Bridge*, and about 300 yards above *Gatewood Bridge*, below the surface of the water in the old *Eau*, - - - - - - -	9	6½

Consequently,

	F.	I.
15th. The surface of the river *Torne*, at the birch tree below *Rosington Bridge*, is higher than the surface of the *Dunn*, at the *Crimpsal*, by - - - - - -	0	4
16th. And the surface of the *Torne*, at the entry of the *Participants Drain*, is lower than the surface of the *Dunn* at the *Crimpsal*, by - - - - - -	5	2½

LEVELS from *Criokbill Nook* to *Rosington Bridge*.

	F.	I.
17th. The general surface of *Wadworth Carr*, near *Crookbill Nook*, above the surface of the *Torne*, at *Crookbill Nook*, as was taken 29th July, 1762, - - - -	0	9
18th. The mean surface of one of the lowest slades near *Crookbill Nook*, above the surface of the *Torne* there, - - - - - - - -	0	1½
19th. The mean surface of the lowest part of *Holme's Carr*, opposite *Crookbill Nook*, below the surface of the *Torne* there, - - - - - - -	0	9½
20th. The general surface of *Potterick Carr*, in the meadows adjoining to *Crookbill Nook*, below the surface of the *Torne* there, - - - - - - -	1	2¾
21st. The height of the bank of the *Torne*, above water, at some of the lowest places on the *Holme's Carr* side, near *Crookbill Nook*, and which the *Torne* is said very rarely to over-top,	0	11
22d. Ditto, on the side of *Potterick Carr*, - - - - - -	0	11¼
23d. Surface of the *Torne*, at the lowest part of *Potterick Carr*, called the *Toad Holes*, below the surface of the *Torne*, at *Crookbill Nook*, - - - - - -	1	8
24th. Surface of the *Torne* just below *Rosington Bridge*, including the fall of 2½ inches there, below the surface of the *Torne*, at *Crookbill Nook*, - - - - -	3	5

Consequently,

	F.	I.
25th. From the general surface of the lowest part of *Holme's Carr*, near *Crookbill Nook*, to the surface of the *Torne*, at *Rosington Bridge*, there is a fall of - - - - -	2	7½

LEVEL from the old *Eau* to *Cantley Common.*

	F.	I.
26th. July 30th, 1762, found the riſe from the ſurface of the water of the old *Eau*, to the top of *Cantley Common*, in the loweſt part of the ridge between the diviſion dyke and the incloſures next *Doncaſter*, - - - - - - -	15	$0\frac{1}{2}$

OBSERVATIONS.

27th. From my view of the country, it appears, that there is a fall of ſome feet from low water mark in the river *Dunn*, near *Thorne Sluice*, to low water mark in the *Trent*, at *Authorpe Sluice*; and from the above levels, Articles 7th and 14th, it appears, that the ſurface of the *Thorne*, at the beginning of the *Participants Drain*, is lower than the *Dunn* at the *Crimpſal*, by 5 feet $2\frac{1}{2}$ inches; but as this will ſcarcely balance the difference at *Doncaſter Lock*, it follows, that the *Torne*, from the entry of the *Participants Drain*, would have a fall into the river *Dunn*, at or near *Thorne Sluice*, at leaſt equal to the ſum of the falls of the four locks upon the river *Dunn* below *Doncaſter*, and therefore has at leaſt an equal one into the drain leading to *Authorpe Sluice*, which may probably amount in the whole to 12 or 14 feet, beſides the 5 feet $2\frac{1}{2}$ inches above mentioned.

28th. From my view of the country, it further appears, that there is no paſſage from *Potterick Carr* to the *Dunn*, without traverſing the ridge of hills extending from *Loverſal* to *Hatfield*, without going below *Hatfield*; and ſince the ſame point can be attained by following the valley of the *Torne*, I therefore look upon the cutting through the high ground, at *Cantley Common*, in order to come at the ſame point, as quite out of the queſtion; and to traverſe the aforeſaid ridge of hills, after paſſing through thoſe high grounds, will be leſs eligible than traverſing the ſame at the out-gang gate, and finding the ſhorteſt way to the *Dunn*.

29th. It is generally looked upon, that a capacity of reducing the ſurface of the water in the drains 2 feet under the general ſurface of the loweſt lands to be drained thereby, to be effectual for draining purpoſes, and therefore whatever means are capable of producing this effect, will anſwer the end as well as if they were capable of making a greater reduction, becauſe the ſurface of the water being too much reduced, with reſpect to the ſurface of fen lands, is found to hurt the fertility thereof.

GENERAL

GENERAL SCHEME.

NOW, with refpect to the general drainage of the country, I take it for granted, that what will drain the loweft flades of *Wadworth Carr*, near *Crookhill Nook*, will, by proper leading drains, do for all the lands that lay further up the country; but as there appears to be from the levels, Articles 17th and 20th, a fall of almoft 2 feet from *Wadworth Carr* into *Potterick Carr*, which would be fufficient for the drainage of the former, yet, was the down-fall waters of *Wadworth Carr* and country above let down, fo as to communicate with the drains of *Potterick Carr*, the former would over-ride, and thereby prevent the drainage of the latter, unlefs both were carried feparately to a point where a fufficient declivity might be obtained, fo as to carry off both without affecting each other. This purpofe may be obtained by cutting new drains feparate from the river *Torne*, fo as to deliver their water into the *Torne*, at the birch tree, below *Rofington Bridge*, before mentioned (Art. 11.) and ftill more effectually was the river fcoured out, and a bridge built at *Oakley Dam*, where, from Art. 12 and 13, it appears, that $15\frac{3}{4}$ inches of level might be obtained in little more than 100 yards, the lofs of which is a great detriment to the grounds lying on both fides of the river, between the faid birch tree and *Oakley Dam*, during which fpace the river being deeper than in moft other places, would reduce its furface a great part of that quantity lower than at prefent.

To this fcheme will probably be objected, that the down-fall water of a large tract of country being brought down into the *Torne* at the birch tree, by more direct paffages than heretofore, will be the means of overflowing the meadows below the faid point, and alfo raife the waters in the out-fall drain to a greater height than they would otherwife do. And it muft be acknowledged, that fomething of this would take place, though in fo fmall a degree, as fcarcely to be fenfible at fo great a diftance from the out-fall; for it muft be allowed, that in wet feafons the fame quantity of water muft be difcharged, the only difference is in the time. It muft alfo be allowed, that the water which comes down the drains to the birch tree, muft otherwife have come down the *Torne* to the fame point, and therefore the water of the *Torne* will be eafed by that quantity. The time therefore can only be affected by that part which comes down to the drains quicker than it would have done by the *Torne*; but then in confequence of this quicknefs being nearer its out-fall, and coming by a more direct road, it will generally happen that the bulk of the down-fall coming by the drains will be gone off, before the bulk of the land waters that come from other places at a great diftance by

the meandring courſe of the *Torne* are arrived; and conſequently, in ſuch caſes, the rapidity of the waters coming down will, upon the whole, be rather abated than increaſed.

But if this reaſoning, however true and explicit, ſhould not prove ſatisfactory to thoſe who are to get nothing by perceiving the truth thereof, I ſee no way of ſteering clear of the objection, but by bringing a new drain from the river *Dunn*, entirely independent of the river *Torne*; and I do not find any better way of doing this, than by beginning at ſome proper point upon the river *Dunn*, below *Stainford* lock, and above *Thorne* ſluice, from thence traverſing the level moors, and leaving *Gatewood* to the north, to approach near the *Torne* at *Gatewood Bridge*, and leaving this bridge, as well as the whole river *Torne*, on the ſouth, to follow the low meadows quite away to *Potterick Carr*, and through the ſame up *Wadworth Carr*, &c.

In this caſe, it would be neceſſary to erect a ſmall ſluice at the out-fall of this drain into the *Dunn*. This method would effectually drain, not only all the country above *Roſington Bridge*, but be of great ſervice to the lands through which it paſſed below, and might be executed at a moderate expence; for though the diſtance is conſiderable, yet there is ſo great a ſufficiency of level, as appears by Art. 27, that a ſmall drain would anſwer the end. This drain would be ſomewhat ſhortened, and the outfall ſluice avoided, in caſe the propoſed ſcheme for making a navigable communication between the *Dunn* near *Thorne Sluice*, and the *Trent* near *Authorpe Sluice*, ſhould take place; in which caſe, the two ſchemes would be of mutual aſſiſtance to each other. Yet as the execution of this ſcheme of drainage, in either method, however practicable in nature and art, would neceſſarily paſs through and ſever many properties, how far it may be practicable reſpecting mens intereſts and opinions, I cannot take upon me to ſay.

SCHEME for POTTERICK CARR.

I come now to conſider what may be done towards the drainage of *Potterick Carr*, independent of the reſt of the country, by ſuch methods as lay within a narrower compaſs, and as it were within the diſtricts of the corporation of *Doncaſter*, and proprietor of *Loverſal*. And here two methods offer themſelves; one by a ſubteraneous paſſage from *Potterick Carr* to the river *Dunn*, by way of the *Crimpſal*; the other by way of *Stecking Dyke*, which appears to be the antient out-fall drain for *Potterick Carr* into the *Torne*, at or near *Roſington Bridge*.

1ſt. With

1ſt. With reſpect to a paſſage from *Potterick Carr* to the *Dunn* above *Doncaſter*, it appears, Art. 7, that when the levels were taken, there was a fall of 4 feet 4 inches from the ſurface of the old *Eau* to the ſurface of the river *Dunn*, the diſtance being about 2 miles. It appears alſo, Articles 5, 6, 7, and 8, that the ſurface of the old *Eau* at that time was about 10 inches below the general ſurface of the *Carr*; therefore a capacity of running off the ſurface of the old *Eau* 14 inches lower than at preſent, would, with proper internal drains, compleat the drainage of this *Carr*, and ſtill there would remain 3 feet 2 inches fall from the water of the old *Eau* to the ſurface of the *Dunn*; but as the verge of the *Carr*, near *Balby* out-gang gate, is about a mile nearer to the *Dunn*, to which all the water of the *Carr* would be brought, in open drains, with very little loſs of level, there would be 3 feet deſcent for the ſubterraneous paſſage, which from this point would not, in the neareſt direction, be above a mile, which is ſo large an allowance of deſcent, that ſuppoſing a clean bottom carried upon a dead level from the ſurface of the *Dunn*, a drain of 3 feet wide would ſufficiently diſcharge the water.

The diſadvantages attending this ſcheme would be, that whenever the ſurface of the *Dunn* ſhould, in rainy ſeaſons, be kept higher than 3 feet above its common pitch, which I ſuppoſe it ſometimes is for weeks together, that then there could be no drainage at all; but, on the contrary, without the help of a ſubterraneous ſluice, the water of the *Dunn* would run into the *Carr*.

This inconvenience would, in great meaſure, be obviated by carrying the drain ſo low as to fall into the river *Dunn*, between the water-engine and the bridge at *Doncaſter*; for this would gain an addition of 5 or 6 feet of level. And though, in the height of great floods, I ſuppoſe there is not a great deal of difference of the *Dunn*'s ſurface above and below the engine-dam, yet I ſuppoſe that the water rarely continues there for any length of time together, ſo as to be 3 feet higher in the engine-tail than the ordinary ſurface of the *Dunn*, at the *Crimpſal*, oppoſite *Newton*. So that the drainage being ſtopped but for a little time together, would be ſufficiently performed by intervals: but then, as this will create about three quarters of a mile addition of drain, and thereby add to the tedioufneſs and expence of an otherwiſe tedious and expenſive job, it will ſtill remain a queſtion, how far this method of drainage may be eligible, eſpecially when 'tis conſidered, that, ſhould a running ſand be met with in this paſſage, it might prove an inſurmountable difficulty, and the work be obliged to be deſerted, after great expences incurred thereupon.

2d. With

2d. With reſpect to a drainage into the *Torne*, if *Stecking Dyke* was carried down on the north ſide of the river, and dropt into the *Torne*, at the birch tree, below *Roſington Bridge*, this ſcheme would be undeniably the beſt of any; for to this place, from the old *Eau*, there is near upon the ſame fall as into the *Dunn*, at the *Crimpſal*, oppoſite *Newton*, with an opportunity of making a drain of any given capacity that may be required; and as it appears, from Art. 21 and 22, that the waters of the *Torne* don't riſe in time of floods above a foot perpendicular, the flood water of the *Torne* can never over-ride thoſe of the drain: and whatever force may be ſuppoſed to remain in the objection to the delivering the down-fall water of the whole country into the *Torne* at this point, it will entirely vaniſh when applied to *Potterick Carr* alone; for being of ſo much leſs extent, and nearer to its out-fall, and having ſo good a declivity, its water will be certainly diſcharged before thoſe from the different parts of the country are come down; and in long-continued rains it is plain that when the *Carr* is once overflowed to a certain height (as is the caſe at the cloſe of winter, when ſurface waters are moſt annoying) that the preſent diſcharge of water from the *Carr*, at thoſe times, will be juſt equivalent to its diſcharge of water in the ſame time when in a ſtate of drainage.

But I will now ſuppoſe the worſt, and take it for granted that nothing can be done but by ſuch lawful means as may be put in practice within the grounds of *Doncaſter* and *Loverſal*.

It appears by the levels, Art. 9 and 10, that from the ſurface of the old *Eau* to the lower ſide of *Roſington Bridge* is a fall of 10½ inches, and from thence to the loweſt part of the ſtraight cut, extending about a furlong below the bridge, is 10½ inches more, in the whole 1 foot 9 inches; but as a reduction of the ſurface of the old *Eau* of 14 inches below its then ſtate has been ſhewn ſufficient for drainage, there will ſtill remain 7 inches fall from the old *Eau* to the point laſt mentioned, which is amply ſufficient, as the diſtance does not exceed a mile and half.

Now the ſtraight cut aforeſaid, below *Roſington Bridge*, (which paſſes through the bounds of the corporation of *Doncaſter*, or Mr. Dixon, of *Loverſal*,) plainly appears to have been made with a view to the drainage of *Potterick Carr*: for by cutting off the loops of the old river, and making a more free paſſage for the *Torne*, the ſurface of the water would naturally be reduced at the tail of *Stecking Dyke*, and conſequently afford a better fall from the *Carr*; and even by this conſtruction, had the whole been done in a proper method, and with proper dimenſions, a drainage might have been accompliſhed, and with good management preſerved to this day: but at preſent I would rather adviſe to let

the

the *Torne* continue its present courſe, and to cut a new drain on the north ſide thereof, through the ſaid lands, from the loweſt point of the ſaid ſtraight cut, up to *Stecking Dyke*; and either by ſcouring out and enlarging *Stecking Dyke*, or by cutting a new drain in lieu thereof, this, with proper internal drains within the *Carr*, will reduce the water 2 feet 7 inches within the general ſurface of the loweſt lands in dry ſeaſons, unleſs held up to a greater height for the uſe of cattle.

It appears from Art. 21 and 22, that the greateſt riſe of the *Torne* in time of floods at *Crookhill Nook* does not exceed 1 foot perpendicular; but there is reaſon to ſuppoſe it may be ſomewhat more at the point before mentioned, poſſibly 15 inches, and therefore it will be neceſſary to place a ſluice or doors at the tail of the drain to ſhut againſt the water of the *Torne* at ſuch times, and prevent their reflowing into the *Carr*; yet, if the drains are made of ſufficient depth and capacity to run off the waters of the *Carr* to the dead level of 2 feet 7 inches below ſoil, thoſe drains will be ſufficient to hold water, ſo as to drain by intervals without overflowing the ſurface of the *Carr*.

It is poſſible the ſame objection may ſtill be urged againſt this ſcheme as againſt the former, of going down to the birch tree, viz. that of bringing down the waters more ſuddenly upon the lands below; but for this, in the preſent caſe, there is moſt evidently not the leaſt foundation; for ſince it will be neceſſary to maintain a pair of doors to ſhut againſt the *Torne* in time of floods, it is plain the drainage water can make no addition while its doors are ſhut; and as they muſt eſcape when the bulk of the floods in the *Torne* are ſpent, it muſt contribute to the carrying off the whole more equally than at preſent. And ſince this ſcheme can be executed within the grounds of the parties concerned, and cannot poſſibly, even in appearance, prejudice thoſe of any other, I apprehend there can be no doubt of the legality thereof; and as this ſcheme can be executed at much leſs expence than any other, for my own part, I think it merits trial.

I hope what has been ſaid will be ſufficient to let the proprietors of *Potterick Carr* ſee clearly the nature of this buſineſs, and to determine them in the choice of a method: when that is done, I ſhall be ready to make what further obſervations may be neceſſary, in order to lay down the particular plan and dimenſions, and form an eſtimate thereupon.

With reſpect to *Holmes Carr*, it will readily occur, from what has been ſaid, that there cannot be the leaſt difficulty; for ſince there is 2 feet 7 $\frac{1}{2}$ inches fall from the loweſt parts oppoſite *Crookhill Nook* to *Roſington Bridge*, that nothing more is neceſſary than to put the

the banks againſt the *Torne* into proper repair, and to make proper drains to carry the down-fall water into the *Torne* at, or immediately below, *Roſington Bridge*, on the ſouth ſide of the river, with proper gates to ſhut againſt the floods, as before mentioned: or otherwiſe, by an under-ground tunnel or fox, to communicate its waters to the drain propoſed for *Potterick Carr*, which, in this caſe, muſt be ſomewhat enlarged on this account.

Auſthorpe, September, 1762. J. SMEATON.

ESTIMATE for draining *Potterick Carr*, *Holmes Carr*, and *Wadſworth Carr*, by a paſſage from *Potterick Carr*, by *Balby* Out-gang gate and *Spanſdyke*, to the river *Dunn*, below the engine at *Doncaſter*; the tail of the drain to be laid 8 feet below the mean ſurface of the *Carr*, and to riſe 1 foot to the Out-gang gate.

	£.	s.	d.	£.	s.	d.
To digging out the tail-drain for an arch, length 5 chains, in order to get round the engine into Mr. *Copley*'s meadow, adjoining to *Crimpſal*; mean depth 10 feet bottom, width 6 feet, and to batter half a foot in a foot a perpendicular, containing 1760 cube yards, at 3½ *d.* per yard, - - - - - - -				25	13	4
To walling the ſides 4½ feet high, which if done with *Extrop* ſtone, or brick length wall, may be done for 14 *s.* per rood, and for 1 chain there will be 9 rood 3 yards, - - - - - -	6	12	0			
The floor being ſet with *Extrop* ſtone, 9 inches deep without mortar, if done for 1 *s.* 3 *d.* per yard, each chain contains, at 5 feet wide, 37 yards, -	2	6	3			
To arching the ſame with brick, at 5 feet ſpan, ſo as to riſe 18 inches, the exterior curve will contain 7½ feet breadth, and in 1 chain at brick length thick, 7 roods 6 yards - - - - - -	5	10	0			
Value of 1 chain arching, - - - - - -	14	8	3			
Which in round numbers we will call, - - - -	14	10	0			
To 5 chains of arching, at 14 *l.* 10 *s.* per chain, - - - -				72	10	0
To ramming behind the walls, fitting-in and righting-up earth, at 1 *s.* per yard, -				3	13	4
To temporary damages, at 1 *d.* per yard, upon the ſurface opened, containing 660 yards,				2	15	0
To extra work, ſecuring the apron, making a front wall next the river, and hanging a ſluice-door to prevent the water of the river *Dunn* from reverting into the *Carr* in time of floods, - - - - - - - - -				20	0	0
Carried over £.				124	11	8

	£.	s.	d.
Brought over	124	11	8
From the aforeſaid drain for 5 chains, through Mr. *Copley*'s cloſe, and from thence 24 chains through the *Crimpſal*, total length 29 chains, may be an open drain, which at 9 feet mean depth, 6 feet bottom, and 4 feet batter per yard perpendicular, turns out 11494 yards, at 3 *d*. - - - - - - -	143	11	
The mean width of the cut at top will be 30 feet, which in 29 chains produces 6386 yards, equal to 1 acre, 1 rood, 11 perches, and each bank will nearly occupy the ſame ſpace, but this is ſuppoſed to be left of half value, ſo that, for the two banks we reckon 1 acre, 1 rood, 11 perches, and in the whole 2 acres, 2 roods, and 22 perches, which if valued at 60 *l*. per acre, comes to - - - - - - -	158	5	0
From *Crimpſal*, up *Spanſyke Cloſes*, 26,26 chains, mean depth 12 feet, with 6 feet bottom, and 4 to 3 ſlopes, will turn out 16995½ yards, at 3 *d*. - - -	211	18	10½
The mean width at top will be 38 feet, which at 26,26 chains long, makes 7315 yards, equal to 1 acre 2 roods 2 perches, which doubled for the cover makes 3 acres and 4 perches, which if valued at 50 *l*. - - - - - - - -	155	0	0
A bridge acroſs at the *Extrop Road*, - - - - - - -	30	0	0
From the top of *Spanſyke Cloſes* to the entry upon of the little moor, is 18½ chains, the mean depth 16 feet. The digging out a 6 feet bottom, with half a foot batter, in a foot high, will turn out 10664 cube yards, which at 4 *d*. comes to - - -	177	14	8
To arching 18,5 chains, at 14 *l*. 10 *s*. - - - - - - -	268	5	0
To ramming, filling, and righting the ground, at ½ *d*. per cubic yard, - -	22	4	4
To temporary damages, at 1 *d*. per yard ſuperficial of the ground opened, 3138, comes to	13	1	6
From the entry of the little moor acroſs the ſame to the baſe of the hill, about one chain within the *Green-Lane*, is 23 chains, mean depth 17 feet; the digging out a 6 feet bottom at ½ a foot batter, in 1 foot riſe, will turn out 13859 yards, which at 4 *d*. a yard comes to - - - - - - - - -	230	19	8
To 23 chains of arching, at 14 *l*. 10 *s*. - - - - - -	333	5	0
To filling in 13859 yards, at ½ *d*. - - - - - - -	28	17	5½
From the baſe of the hill, one chain upon the ſame being at a medium 20 feet deep, with bottom and ſlopes as before, containing 782 cube yards, at 5 *d*. - - -	16	5	10
To arching ditto as before, - - - - - - - -	14	10	0
To filling ditto, 782 cube yards, at ½ *d*. - - - - - -	1	12	7
To open caſting on the ſide of the hill next the *Carr* one chain, mean depth 12 feet, with a 6 feet bottom, and ſlopes as before, - - - - - -	15	0	0
To open-caſting, arching, and filling one chain more, mean depth 16 feet, - -	27	0	0
To open-caſting, arching, and filling one chain, mean depth 20 feet, as on the other ſide of the hill, - - - - - - - -	33	0	0
Charge of the out-fall drain, excluſive of the hill, - - - - -	2005		
The length of the under-ground paſſage through the hill, which cannot be conveniently open caſt, is 13 chains, that is 286 yards; but as the quality of the matter is not known at the depth it is to paſs, it is impoſſible to eſtimate the charge of getting through it; if it turns out any kind of matter that will ſtand unſupported till arched a fathom at a time, it may be done for about 4 *s*. per yard, pitting included; but as it may be attended with ſome extra trouble, if we allow 2 *l*. 10 *s*. per yard, then 286 yards at 2 *l*. 10 *s*. come to - - - - - - - - -	715		
Carried over £.	2720	2	7

	£.	s.	d.
Brought over	2720	2	7
To extra work in fixing a drawgate at the entry of the subterraneous passage, in order to take off the water, to repair or inspect any thing within, and which will also serve for holding in water for the cattle in dry seasons, - - - - -	20	0	0
Estimated expence of the out-fall drains - - - - - -	2740	2	7

N. B. The whole length is 119 chains, or 1 ½ mile wanting one chain.

Mother drains, barrier bank, &c. within the *Carrs*.

	£.	s.	d.
To digging a mother drain from the entry of the subterraneous passage to the old *Eau*, being in length 1 ¾ mile, to be 21 feet top, 9 feet bottom, and at a medium 6 feet deep, containing 30800 cube yards, at 2 *d*. - - - - -	256	13	4
To continuing the said drain from the old *Eau* to *Crookhill Nook*, in order to receive the water by foxes, from *Holmes Carr* under the *Torne*, and from *Wadworth Carr* under *Catherine Well Water*, being in length 1 ¼ mile, to be 19 feet top, 9 feet bottom, and at a medium 5 feet deep, containing 17111 yards, at 2 *d*. - - - - -	142	11	2
To the making a fox, about 2 yards wide and 1 yard high, for taking the water from *Holmes Carr* under the river *Torne*, - - - - - - -	60	0	0
To a ditto, about a yard square, from *Wadworth Carr*, with a shuttle for regulating the water, that it does not come down faster than the mother drains in *Potterick Carr* will vent it - - - - - - -	55	0	0
To cutting a back drain behind the bank of the *Torne* in *Potterick Carr*, and thereby strengthening the bank against the river, being in length about 1 ½ mile, to be 3 yards mean width, and a yard deep, cutting and banking at 2*d*. per yard, - -	66	0	0
To ditto behind *Crookhill Bank*, 1 mile (or so far as may be found necessary) of the same dimensions, - - - - - - - -	44	0	0
To cutting a mother drain within *Holmes Carr*, parallel with the general course of the river, avoiding the loops, and therewith forming a bank against the same, leaving 20 feet foreland in the nearest places; the length supposed 2 ½ miles, (more or less as may be necessary) to be 5 yards top, 2 yards bottom, and at a medium 4 ½ feet deep, containing yards, at 2 *d*. - - - - - - -	192	10	0
To cutting a mother drain, in like manner, in *Wadworth Carr*, disposing the earth bank fashion, as before-mentioned. The drain to be 4 ½ yards top, 1 ½ bottom, and at a medium to 1 ½ deep, supposing the length 1 ½ miles (more or less, as may be necessary) will contain 11880 yards, at 2 *d*. - - - - -	99	0	0
To strengthening *Catherine Well Water Bank* against *Wadworth Carr* by a back drain, 3 yards wide and 1 yard deep, supposing the same 1 mile (more or less, as may be required)	44	0	0
To banking on both sides the drain by the side of the road over *Wadworth Carr*, which brings down the water of some springs, and also for making catch-water drains to conduct the upland water into the river, supposing the whole to be 2 ½ miles, (more or less, as may be wanted) 3 yards wide and 1 deep, - - - - -	110	0	0
Estimated charge of the internal works - - - - - - -	1069	14	6

GENERAL ACCOUNT.

		£.	s.	d.
The out-falls drain,	- - - - - - - †	2740	2	7
The internal works,	- - - - - - -	1069	14	6
Contingent expences upon the whole, the perforation of the hill excepted,	- -	400	0	0
Total	* £.	4209	17	1

N. B. The ſum marked thus † was in the original 2732 *l.* 6 *s.* 0 *d.* and the total marked thus * was 4202 *l.* 0 *s.* 6 *d.*

OBSERVATIONS.

1ſt. In caſe a red ſand rock ſhould be found in the hill, at the level of the drain that will ſtand of itſelf, it may be done for 1 *l.* 5 *s.* a yard, but in caſe it ſhould be a ſoft clay, or running ſand, it may coſt 10 *l.* a yard.

2d. In caſe of ſuch a ſand or clay, it will be adviſeable to ſink for a firmer matter below, in which caſe, the water may be carried under the hill in manner of an inverted ſyphon.

3d. If a red ſand rock ſhould lay in a right line between the engine and *Carr*, as the diſtance is only 65 chains, it might be cut for about 1828 *l.*

4th. If ſuch a rock ſhould be found between the top of *Spanſyke Cloſes*, in a right line to the *Carr*, the length being 33 chains, the whole expence of the out-fall drain will be done for 1751 *l.* But

5th. If this laſt ſpace ſhould be the ſame matter as ſuppoſed in the eſtimate for Outgang gate, the out-fall drain would be done this way for 2659 *l.* but the hazard greater.

6th. As much depends upon the quality of the matter, it would be adviſeable to bring this affair to a certainty, by ſinking or boring.

7th. The charge of carrying the drain from the top of *Spanſyke Cloſes* acroſs the little moor to the entrance of the hill, will be ſomewhat cheaper by an open drain than by arching; but as the cut and banks would occupy between 50 and 60 yards broad, would be leſs eligible to the land owners, and the drain more liable to obſtruction, by matter tumbling from ſuch very high banks.

N. B. The bottom for the arching parts is ſuppoſed to be dug no more than 6 feet wide, though the drain within the walls is purpoſed to be of 5 feet, becauſe the foot of the ſlopes may be cut down perpendicular half a foot on a ſide, when the maſons are ready to put in the walls.

Doncaſter, March 23, 1764. J. SMEATON.

To Mr. SHEPPARD, concerning *Potterick Carr.*

SIR,

IN anſwer to your requeſt, my report is as follows:

That in the dry ſeaſon in July 1762, I found the waters of the old *Eau* in *Potterick Carr* nearly 10 inches below the mean ſurface of the land in the *Carr*, which in the points I tried it was nearly upon a level, which are ſpecified in my report, and to which I refer; that from the ſurface of the water in the old *Eau*, to the ſurface of the river *Torne* juſt below *Roſington Bridge*, I found a fall of $10\frac{1}{2}$ inches, and from thence to the bottom of the ſtraight cut, or river below *Roſington Bridge*, $10\frac{1}{2}$ inches more, making together 1 foot 9 inches below the ſurface of the old *Eau*, as it and the river then were; but it is to be remarked, that the ſurface of the water in the river juſt below *Roſington Bridge* was 13 inches below the firſt apparent joint of the arch on the ſouth-eaſt angle thereof, whereas when I viewed it on the 20th of May laſt, it was nearly 6 inches above the ſame.

I alſo find from my notes taken in 1762, that from the bottom of the ſtraight river aforeſaid, to the birch tree mentioned in my Report, I made 2 ſtations, amounting together to 2 feet 3 inches fall; the firſt below being $11\frac{1}{4}$ inches, and the ſecond $15\frac{3}{4}$ inches; but how far the firſt ſtation of 11 inches extended below the ſtraight cut, I do not now remember, having no remark thereupon, the extent of the corporation's eſtate on the ſouth ſide of the river not being at that time diſtinctly pointed out to me; but I have reaſon to believe that at leaſt 6 inches of the 11 would fall within the corporation's eſtate, ſo that hence I infer, that from the ſurface of the old *Eau*, to the ſurface of the river *Torne*, at the bottom of the corporation's eſtate, as the old *Eau* and river then were, was at leaſt 2 feet 3 inches, and conſequently below the mean ſurface in the

Carr

Carr 3 feet 1 inch, and which I don't doubt but will appear the ſame, whenever the obſtructions, which I apprehend to be ſince formed in the river below *Roſington Bridge*, are removed, ſo as to ſuffer the ſurface of the water to ſubſide to the ſame point upon the bridge, as it was even with in 1762; and conſequently, that with the fall above mentioned, the *Carr* may be effectually drained, as 2 feet below the ſurface is generally eſteemed by the moſt experienced engineers a compleat drainage.

For this purpoſe, I apprehend it will be convenient to cut a new paſſage for the river *Torne* from ſome proper place at or above *Crookhill Nook*, and ſkirting the high ground on *Roſington* ſide, as much as conſiſtent with a ſhort courſe to bring the ſame down to *Roſington Bridge*, and building a new bridge for the new river on the ſouth ſide of the preſent bridge, to carry down the new cut through the corporation's eſtate on the ſouth ſide of the preſent river, and to drop the ſame into the *Torne* at the loweſt point of the ſaid eſtate. This new river being properly embanked, will defend the lower grounds of *Potterick Carr* from the floods of the *Torne*, and by proper drains and tunnels will drain *Holmes Carr*, and the higher grounds to the weſtward of the ſame, without interfering with that of *Potterick Carr*.

The dimenſions of this new river ought to be at leaſt 20 feet bottom, with proper batters, or ſlopes, of at leaſt 1 to 1. The bottom at the tail of the new river to be at leaſt 2 feet below the ſurface of the *Torne* there, as it was in July 1762, that is, 4 feet 6 inches nearly below the ſaid joint in the arch, and to riſe upon a plane regularly inclined, ſo as to be at leaſt 4 feet below the ſurface of the adjacent carrs, where it joins the old river at or above *Crookhill Nook*.

For the drainage of *Potterick Carr*, I would recommend to cut a new drain between the propoſed new river and the old one, beginning at the old river juſt above the tail of the new one, and joining the ſtraight river as ſoon as poſſible, to widen and deepen the ſame in its preſent courſe, ſo as to paſs under the preſent *Roſington Bridge*; and from thence keeping on the north ſide of the old river above *Roſington Bridge*, to join *Stecking Dyke*, widening and deepening the ſame nearly according to its preſent courſe, to the place where the engine ſtood, from thence keeping a ſtraight courſe, or as nearly ſo as the convenience of properties will allow, through the middle of the *Carr* to the north end thereof.

This drain I would recommend to be at leaſt 18 feet wide at the bottom, with ſlopes of at leaſt 1 to 1, and to be at leaſt 5 feet 6 inches below the ſaid joint in the arch, the

bottom

bottom to be carried upon a dead level, and of an equal width as far into the *Carr*, as till it is oppoſite the old *Eau*, from thence to grow gradually narrower and ſhallower, ſo as to be 4 feet deep and 5 feet bottom at the head; this, with proper croſs drains, will reduce the water in the *Carr* to very near the ſame level as the river at the out-fall of the drain. I would further adviſe that a ſluice with doors, pointing toward the *Torne*, be erected at the tail of the drain, to prevent the water of the *Torne* in great rains from over-riding thoſe of the *Carr*, and thereby reverting into the *Carr*, and alſo a ſtop-ſluice with draw-doors upon the tail of the propoſed new river, by ſhutting which, at proper times, the propoſed drain will run at times, when it otherwiſe would not; a ſluice-keeper being appointed to take care of the drawing and ſhutting the ſame, ſo as to prevent their running or penning improperly, on account of the lands above and below.

A catch-water drain round the ſkirt of the *Carr* will be of great uſe, in conveying the water from the uplands into the new river, without entering the *Carr*; but as the country is not very extenſive which at preſent throws down water upon the *Carr*, this expedient need not be put in practice till experience ſhews it to be wanted.

The above reaſoning principally depends upon two points, which I would recommend to the commiſſioners to ſatisfy themſelves upon, viz. whether obſtructions in the river below the corporation's eſtate can or cannot be removed, ſo as to run off the water to the ſame depth as I found it in my ſurvey in July 1762; and ſecondly, whether, in that ſtate of the river, there is or is not the quantity of fall ſpecified, or near upon.

I am, SIR,

Your moſt humble ſervant,

JOHN SMEATON.

P. S. The joint of the arch being a little inclined, I took my meaſure from the loweſt ſide next the water.

The

The REPORT of JOHN SMEATON and JOHN GRUNDY, Engineers, concerning the practicability of improving the *Foſſdyke* navigation, and draining the land laying thereupon; from a view and levels taken in Auguſt, 1762.

THE *Foſſdyke* is an artificial cut or canal, which joins the *Trent* and *Witham* together, by a navigable communication, extending from the *Trent*, near *Torkſey*, to *Brayford Meer*, near the city of *Lincoln*, being in length near upon 11 miles. The river *Witham*, which has its origin near *Poſt Witham*, in *Lincolnſhire*, after purſuing a courſe of about 40 miles, falls into *Brayford Meer*, which being a natural reſervoir of ſeveral acres in ſurface, and having an open communication with the *Foſſdyke*, as alſo with two other ſtill more extenſive lakes, or natural reſervoirs, called *Swan Pool* and *Cuckoo Pool*, their ſurfaces being common, and nearly at reſt, will, conſequently, be nearly upon the ſame level, and riſe and fall together.

The end of the *Foſſdyke* next the *Trent* is ſhut by a lock, having gates pointing both ways, which, of conſequence, equally prevent the waters of *Foſſdyke* from flowing out into the *Trent*, or the waters of the *Trent* from flowing into the *Foſſdyke*, according as each ſurface happens to be lower or higher than the other. The waters of *Brayford Meer*, and conſequently of the *Foſſdyke*, are prevented from running off below a certain height, by a ſhoal in the river *Witham*, between *Brayford Meer* and *Lincoln High Bridge*, called *Brayford Head*, or the *Natural Stanch*. There are alſo three other paſſages for the water of the *Witham*, before it falls into *Brayford Meer*, which are called *Sincil Dyke*, and the two *Gowt Bridge Drains*; the two latter join the former, and fall into the river *Witham* below the ſaid ſhoal of *Brayford Head*, a little above *Stamp End*, which is the loweſt point of the city of *Lincoln*; from hence the waters of the *Witham* make their way through the fens towards *Boſton*; but as the higheſt part of the bottom of *Sincil Dyke* and *Gowt Bridge Drains* is ſeveral inches higher than the top of the ſhoal of *Brayford Head*, thoſe ſerve only as ſlaker drains, to eaſe off the paſſage of the water in time of floods; but *Brayford Head* is conſidered as the gage, weir, ſtanch, or tumbling bay, by which the water of *Brayford Meer* is kept up to a certain height, and diſcharged when above the ſame.

Now there being a great quantity of low grounds, which have their drainage into *Brayford Meer* and into the *Foſſdyke*, and their communications, which cannot, in the preſent ſtate of *Brayford Meer*, be effectually drained, for want of a ſufficient fall from the

the loweſt parts of their ſurface, it is therefore deſirable to the proprietors of thoſe lands that *Brayford Head* ſhould be removed, or at leaſt ſo far lowered, that the water of *Brayford Meer*, and conſequently the *Foſſdyke* water, being ſo much ſunk below its pre-preſent gage ſurface, as to afford a ſufficient declivity from the ſurface of the lands thereinto.

On the other hand, the *Foſſdyke* navigation being at preſent deficient in depth of water, it is equally deſirable to the proprietors thereof that *Brayford Head* ſhould be raiſed.

To reconcile thoſe oppoſite intereſts, and give to each party what they deſire, without injury to the other, is the point at preſent before us.

In the firſt place it is very obvious that, was *Brayford Head* lowered a certain number of inches, and the bottom of the *Foſſdyke* lowered as much, that the lands would be bettered, and the *Foſſdyke* navigation would be in the ſame ſtate as now; and if beyond that the bottom of the *Foſſdyke* was lowered as many inches more as it is at preſent deficient, then the navigation would be bettered alſo, and both ſides would get what they want.

In order to examine the merits of this propoſition, we ſounded the depths of the *Foſſdyke*, and examined the qualities of its bottom, meaſured the width, and took the height of the banks, in a variety of places, between one end and the other, and made what other obſervations we could, in order to inform ourſelves with the circumſtances that would be likely to occur in the execution of ſuch a project: in conſequence whereof, we found that (ſome few places excepted) the bottom was either a rotten peat earth, or elſe a running ſand; and from the efforts that have already been made from time to time, in order to clear the bottom, and by the wharfing up the ſides with piles, plank, and ſtone, as well as from the nature of the ſoil itſelf, it appears to us to be very difficult and expenſive to preſerve the preſent depth of water upon its preſent width; and though we are of opinion that the deepening thereof in the requiſite degree to anſwer the purpoſes aforeſaid, is in nature poſſible, yet, as it appears to us that this deepening cannot be effected without moving one of the banks, in order to widen the ſame, and give a proper foreland thereto, and that in a very conſiderable degree for the greateſt part of the length, it will, in conſequence, not only turn out a very expenſive project, which, by an eſtimate we have made thereof, amounts to upwards of 6000*l.* but be the occaſion of much loſs of time and profit to the proprietors of the navigation while the

the work is executing; and, as it appears to us, will not be ſo eligible even to the land-owners themſelves as the following ſcheme of drainage would be; for it is moſt manifeſt, that no grounds which drain into *Brayford Meer*, *Foſſdyke*, or any of the pools or communications that lay upon the ſame level therewith, can receive any greater prejudice by the preſent height of water in the *Foſſdyke* than heretofore, unleſs it can be proved that *Brayford Head* is now higher than it was, for if it is not, the expence of ſuch deepening muſt in a great meaſure fall upon the proprietors of lands, for whoſe ſake principally it is done, it being no matter which concerns the proprietors of land, how deep the bottom of *Foſſdyke* is below the gage ſurface of its water, but only whether this gage ſurface is higher now than it was; if not, and the leſſors and leſſee of the *Foſſdyke* are diſpoſed to be contented with its preſent depth, rather than be at the charge of deepening, the deepening, with all its conſequences, will then become the buſineſs of the land owners only, except what it ſhall be reaſonable for the *Foſſdyke* proprietors to contribute, for the advantage of a greater depth than at preſent, after all loſſes and damages that they ſhall ſuſtain thereby are made good.

Whether *Brayford Head* is higher now than formerly, is not for us poſitively to determine; and though it is poſſible ſome acceſſion of matter might have come to *Brayford Head* from various cauſes and accidents, yet as the ſhoal is not compoſed of fixt matter, it may notwithſtanding have been upon the whole in a ſtate of diminution, rather than increaſe, ſince the increaſe of traffick, by the paſſing of boats and carriages upon and over it.

Having viewed and taken the levels of various points of the ſurface of thoſe lands which drain into *Foſſdyke*, *Brayford Meer*, or their communications, we find thoſe moſt ſubject to be drowned are as follows.

On the ſouth of *Foſſdyke* are *Lincoln Holmes*, *Bootham* low grounds, *Skellingthorpe* low grounds, and part of *Saxelby* paſture: on the north of the *Foſſdyke* are part of the *Lincoln Common*, *Burton Fen*, *South Carlton Fen*, *North Carlton Fen*, and a ſmall part of *Broxholme*, *Haddow*, and *Saxelby* low grounds, upon the *Till*.

The ſurface of the grounds abovementioned are at a variety of elevations above the level of *Foſſdyke* water; yet the greateſt part thereof were leſs than 3 feet, and we found no conſiderable quantity but what was at the time of this view 1 foot and upwards above the *Foſſdyke*, (the greateſt part being from 1 foot to 1 foot 6 inches) except the *Haſſocks* in *Lincoln Holme*, (being in a manner a bog) a ſmall part of the low ſlade which

extends from the *Foſſdyke* to *Biſhop Bridge* on *Lincoln Common*, and a ſmall quantity in *Saxelby* paſture oppoſite to the *Till*, which were but little elevated above the *Foſſdyke* ſurface. But the loweſt ground of any conſequence, is a ſlade extending from *Cuckoo Pool* to *Saxelby* paſture, which appears to have been the courſe of the *Till* before the *Foſſdyke* was originally cut; this was from 5 inches to about a foot above the ſaid *Foſſdyke* ſurface. At the time when this view was taken, there was at a medium, as before mentioned, 4½ inches water upon *Brayford Head*; from the beſt information there is ſcarcely ever leſs than 3 inches, and in great winter floods, full 4 feet; ſo that it may be reaſonably conjectured, and we have been ſo informed, that in the ſpring of the year, and at all other times until the ſaid flood waters, which have expanded themſelves over that large tract of low grounds above *Lincoln*, are exhauſted, there can ſeldom be leſs than 10 inches water thereon.

The principal opening for the diſcharge of thoſe waters of the *Witham*, and from this tract of land under conſideration, is through *Lincoln High Bridge*, which in the narroweſt part is no more than 15½ feet; beſides which are *Sincil Dyke* and the two *Goat Bridge Drains* aforeſaid, which though greater in width when taken together, yet from laying conſiderably higher, and from thoſe drains being very defective, are not capable of diſcharging more water than the *High Bridge* ſingly.

From hence it appears, that the low lands before mentioned, when once overflowed, their drains having an open communication with each other, muſt remain under water during the winter, and a great part of the ſpring ſeaſon, and are without the compaſs of a compleat drainage in their preſent ſituation.

Imbanking and engines are a general method of drainage, which may be put in practice where nothing elſe can; but the certain expence, and uncertain effect thereof at critical times, have made all drainers prefer the uſe of natural means, where thoſe natural means can be had.

On examining the *Foſſdyke*, we find the general bottom to be about 2 feet 8 inches below the level of *Brayford Head*, in ſome few places leſs; but as they are only ſhort diſtances, they will eaſily be reduced to a proper depth by dredging, ſo that there is wanting 10 inches of depth in order to compleat the navigation to 3 feet 6 inches; for the addition that will be made by 3 or 4 inches of water conſtantly going over *Brayford Head*, will give a ſufficiency of free water for navigating veſſels drawing 3 feet 6 inches. In order therefore to give the *Foſſdyke* this neceſſary addition, and at the ſame time to drain

drain the lands in queſtion without detriment to any other, we propoſe a ſcheme founded on the following facts.

1ſt. That from the ſurface of the river *Witham*, at the lower mouth of *Sincil Dyke*, to the ſurface of the water of *Brayford Meer*, when at its ordinary ſummer's height, is a riſe of 14 inches; but from the ſurface of the river at *Stamford* to the ſame place, is a riſe of 1 foot 7 inches and a half; and from the ſurface of the *Brayford Meer*, to the ſurface by *Bailey's Sluice*, is 2 feet $5\frac{1}{2}$ inches.

2d. That from the ſurface of *Brayford Meer*, to the ſurface of the river *Witham*, at the upper mouth of *Sincil Dyke*, which runs under *Bargate Bridge*, is a riſe of 1 foot 6 inches.

3d. From the ſurface of *Brayford Meer*, to the ſurface of the river *Witham* at *Brace Bridge*, is a riſe of 3 feet 2 inches.

4th. From the natural ſtanch of *Brayford Head*, to the bottom of the river at *Brace Bridge*, forming a natural ſtanch, there is a riſe of 2 feet 6 inches.

5th. That from *Brayford Head*, to the bottom of *Sincil Dyke Drain*, at its higheſt part, near *Bargate Bridge*, is a riſe of 1 foot $7\frac{1}{2}$ inches; and from *Brayford* to the mean higheſt bottom of the *Gowt Bridge Drains*, is 1 foot $3\frac{1}{2}$ inches.

N. B. At the time of this view, the *Sincil Dyke* and two *Gowt Bridge Drains* were all running about 3 inches over their higheſt points.

6th. We found, from our levels and obſervations, that all the low grounds adjoining upon the *Till*, are on ſo high a level above the ſurface of the *Foſſdyke*, that they will have a drainage therein on the decline of floods, except about 40 acres, contained in a narrow ſcreed by the old courſe of the *Till* ſide, from *Haddow Bridge*, about half a mile upwards, the loweſt part of which we found 13 inches above the ſurface of the *Foſſdyke*, and about 20 acres more laying in a ſlade a little higher up, on the north ſide, the loweſt part of whoſe ſurface was 9 inches only above the *Foſſdyke*; we alſo found that the only conveyance for the *Till* oppoſite this ſlade, was an artificial cut or ditch, about 3 feet and a half wide in the bottom, and at this time quite dry.

7th. That

7th. That having examined the ſeveral drains that fall into the *Foſſdyke*, weſt of the *Till*, we find that the bottom of *Dodington Drains* (by its tunnel) is 1 foot $6\frac{1}{2}$ inches higher than the ſurface of the *Foſſdyke*; *Thorney Drain* bottom, near the tunnel, is 6 inches above the ſaid ſurface of the *Foſſdyke*; but the bottom of the ſaid drain, which riſes gradually at about $\frac{3}{4}$ of a mile diſtance therefrom, is 4 feet higher than the ſame. The bottom of the firſt drain on *Kettlethorpe Moor*, near its tunnel, is higher than the ſurface of the *Foſſdyke* by 3 feet 2 inches, the 2d by 1 foot 10 inches, and the 3d by 2 feet 2 inches; the bottom of the drain between *Kettlethorpe* and *Fenton Moor*, by its tunnel, is 1 foot $1\frac{1}{2}$ inch, and that on *Fenton Moor* is 1 foot 7 inches higher, by its tunnel, than the ſurface of the ſaid *Foſſdyke*; and all the ſaid drains riſe conſiderably, as they advance into the land, and the ſaid land is alſo in general conſiderably higher than the bottoms of the ſaid drains, ſo that it is evident that none of theſe drains, nor the lands through which they paſs, can be affected by a riſe of 10 inches in the *Foſſdyke* above the ſurface it then had, viz. 4 inches and a half above *Brayford Head*.

SCHEME for a general drainage and navigation.

1ſt. TO imbank both ſides of the *Foſſdyke*, where wanting, from *Brayford Meer* to the river *Till*, making all good, 5 feet higher than *Brayford Head*, (which, as the flood waters of the *Witham* are propoſed to be kept out of this part of the river, will be ſufficient) and cutting off all communication with *Swan* and *Cuckoo Pools*.

2d. To ſcour out and enlarge *Sincil Dyke*, from its lower mouth near *Stamp End*, to the place where the firſt or northernmoſt *Gowt Bridge Drain* falls into the ſame, bringing up the bottom upon a dead level with the bottom of the river *Witham* at *Stamp End*, making it 25 feet wide at bottom, with proper ſlopes. Then to ſcour out and enlarge the ſaid *Gowt Bridge Drain*, from the ſaid *Sincil Dyke* to the *Witham*, continuing the bottom thereof upon the ſame dead level, and 15 feet broad, with proper ſlopes or batters; and to continue the ſame underneath the *Witham*, by means of an underground tunnel or fox, 14 feet wide and 3 feet deep, with pointing doors on the eaſt end, and draw doors on the weſt end thereof: the river *Witham* to be entirely banked off from falling into this drain. A new drain of the ſame depth and capacity to be continued from the *Fox* to ſuch part of *Swan Pool* as is as deep as the drain.

A drain

A drain of the ſame dimenſions to be continued from *Swan Pool* to *Cuckoo Pool*. The ground taken out of the new cuts from the *Witham* to be diſpoſed of bank-faſhion, leaving forelands of 3 feet on each ſide of the cuts.

3d. To ſtrike out a drain from *Swan Pool*, or from any point of the drain before mentioned, between *Swan Pool* and *Cuckoo Pool*, that ſhall be in a proper direction for croſſing the *Foſſdyke*, and to purſue the ſame to *Biſhop Bridge*. This drain ſhould be 14 feet bottom, with proper ſlopes, and to riſe from the aforeſaid dead level one foot between *Swan Pool*, or the point aforeſaid, and *Biſhop Bridge*; the ſaid drain to communicate under the *Foſſdyke* by means of a ſubteraneous tunnel, or fox, of 12 feet wide and 3 feet high; the earth of the cut from *Swan Pool* to the fox to be diſpoſed of bank-faſhion, with forelands of 3 feet.

N. B. A bridge will be wanting over this drain on *Lincoln Common*.

4th. To erect a lock with 2 pair of gates, upon the paſſage between Mr. ELLISON's wharf and *Brayford Meer*, the gates to be pointed towards *Brayford Meer*; the whole to be built high enough to pen the water of the higheſt floods of the *Witham* from flowing into the *Foſſdyke*.

5th. To ſcour out the river *Witham* where wanting, from *Brayford Meer* to *Brace Bridge*, and to embank the ſame on the weſt ſide, ſo as to be flood proof, and continuing the ſame on the ſouth weſt ſide of *Brayford Meer*, to join the ſouth ſide of the ſaid lock; and to conſtruct a ſimilar bank on the north ſide of the ſaid lock to the high land on the north ſide of *Foſſdyke*, making the ſaid banks 30 feet ſeat, 6 feet top, and 6 feet high; the river between *Brayford Meer* and *Brace Bridge* to be made at leaſt 36 feet wide, and its bottom ſo deepened as to form a regular inclined plane one foot deeper than the preſent level of *Brayford Head* at that end thereof, and of the preſent depth at *Brace Bridge*. The bank to be formed partly from its back drain 10 feet wide at top, 4 at bottom, and 3 deep; the reſt from the ſaid widening or deepening the river, and to be placed 40 feet from the border of the river.

6th. To further ſcour out and enlarge the *Sincil Dyke* between the two lower mouths of the *Gowt Bridge Drains*, ſo as to be of the ſame dimenſions as before ſpecified for the lower part thereof, and from the lower mouth of the ſecond or ſouthernmoſt *Gowt Bridge Drain*, to ſcour out and enlarge the *Sincil Dyke* to its upper mouth at the river *Witham*, ſo as to be 12½ feet bottom, with proper ſlopes, and the bottom to be carried nearly

upon

upon a dead level from the ſaid point to the river *Witham*. And in like manner and proportion the ſecond or ſouthernmoſt *Gowt Bridge Drain* to be ſcoured out, and enlarged, from the ſaid point to the river *Witham*, and to erect two ſtaunches; one upon the upper mouth of the *Sincil Dyke*, the other upon the upper mouth of the ſaid *Gowt Bridge Drain*, both opening into the river *Witham*: the *Sincil Dyke* ſtaunch to be gauged to 1 foot 4 inches higher than the preſent level of *Brayford Head*; that is lower by $3\frac{1}{2}$ inches than the higheſt part of the preſent bottom of the ſaid drain, and the *Gowt Bridge* ſtaunch to be gauged one foot $2\frac{1}{2}$ inches above *Brayford Head*; that is one inch lower than the medium of the two *Gowt Bridge Drain* bottoms; the ſaid ſtaunch to have a clear waterway of $12\frac{1}{2}$ feet each, and their cills to be laid as low as the bottoms of their reſpective drains.

7th. To erect a ſtaunch at or near *Lincoln High Bridge*, on the weſt ſide thereof, the top of which to be gauged to 10 inches above the level of the preſent *Brayford Head*, and to be filled up with doors capable of allowing a clear water-way of $15\frac{1}{2}$ feet at leaſt, and the cills of theſe doors to be laid at leaſt 2 feet 8 inches below the level of the preſent *Brayford Head*; after which, the ſaid ſhoal of *Brayford Head* to be removed, and the whole contents of the river, between *Brayford* and *Lincoln High Bridge*, to be taken away as deep as the cill of the ſaid ſtaunch.

N. B. If inſtead of erecting the ſaid ſtaunch at the *High Bridge*, it be erected 100 feet to the weſt of the ſaid bridge, with a pair of doors pointing towards *Brayford Meer*, it will form the upper gates of a lock, for making a communication between the *Foſſdyke* and intended navigation from the *High Bridge* to *Boſton*.

8th. To ſcour out, enlarge, and embank the *Till*, from its junction with the *Foſſdyke* at *Haddow Bridge*, to about 1 mile above the ſame, ſo as to be capable of ſuſtaining and confining the greateſt floods within its banks, and to lay a ſmall ſubterraneous tunnel of about 6 inches ſquare under the ſame, to convey the down-fall and ſoakage waters from the low grounds laying weſt thereof, into *Burton* main drain, by which they will be drained in conjunction with *Carlton* and *Burton Fens*, &c. without any annoyance thereto.

N. B. It is propoſed that the ſaid cut ſhall be at leaſt 12 feet wide at bottom, and its banks 5 feet higher than *Foſſdyke* ſurface at low water.

9th. The gauged bar of *Torkſey Lock*, (being $10\frac{1}{2}$ inches in height) to be removed, and the framed bar to become the gauge at *Torkſey*.

10th. To

10th. To erect a pillar of ftone, in or by the fide of *Brayford Meer*, whofe top to be 1 foot 2 inches above the level of *Brayford Head*; to be fo placed that the water thereof may flow freely round and upon the faid ftone, with a fet-off or confpicuous mark, 1 inch below the faid top.

The OPERATION of the foregoing Conftructions.

1ft. AS there appears, from the facts before ftated, to be a fall from the furface of *Brayford Meer* to the furface of the river *Witham*, at the lower end of *Sincil Dyke*, of 14 inches in its common fummer's ftate; and that from the lower end of *Sincil Dyke* to *Stamp End* there is a further fall of $5\frac{1}{2}$ inches, chiefly owing to the obftructions of the river *Witham* between thofe two points, and alfo a yet further fall from thence to *Baily's Sluice*, of 10 inches; it follows, that whenever the Commiffioners for the navigation between *Lincoln High Bridge* and *Bofton* fhall be pleafed to execute this part of their undertaking, according to the act, that there will then be a much more confiderable fall obtained: or, in the mean time, if they will fuffer the drainers above *Lincoln* to deepen the river between *Stamp End* and *Sincil Dyke*, that then this $5\frac{1}{2}$ inches fhall be added to the former 14 inches, fo as to make 1 foot $7\frac{1}{2}$ inches fall from *Brayford Meer* to the lower mouth of *Sincil Dyke*. However, not to build this fcheme upon the probable execution of another, we will, for the prefent, fuppofe every thing within that act to ftand as it now does, ftill there will be a fall of 14 inches gained to *Brayford Meer*; and fince the general furface of the low grounds (before fpecified) that drain into *Brayford Meer* were from a foot to 18 inches above the furface of that meer, at the time of this view (*Brayford Meer* being then $1\frac{1}{2}$ inch higher than its loweft ftate) it follows, that there will be a fall of above 2 feet 6 inches from the general furface of the low lands to their out-fall at *Sincil Dyke* tail; and as the flood waters of the *Witham* (which, for want of a fufficient difcharge at *Lincoln*, have chiefly contributed to the overflowing of the fame) will be held off by the propofed bank from *Brayford Meer* to *Brace Bridge*, there is no doubt but that the fall above mentioned will be fufficient for the general drainage of the low grounds aforefaid. It is true that fome places, within the low grounds afore fpecified, lay lower than the general furface by feveral inches; but as the quantities fo circumftanced are of no confiderable extent, and as thofe very pieces will, by the execution of this fcheme, be in better condition, as to drainage, than the greateft part of the low grounds now are, no reafonable objection can be

be drawn againſt the ſcheme in general from thoſe particular places; for as to the low ſlade of the old *Till*, between *Cuckoo Pool* and *Saxelby Paſture*, it may be provided for by carrying the main drain through it, and will, of conſequence, be moſt early in receiving benefit; and yet this ſlade will, at a medium, lay 2 feet, and its very loweſt parts next *Cuckoo Pool* 19 $\frac{1}{2}$ inches above ſummer's water, even ſuppoſing nothing was to be done below the tail of *Sincil Dyke*..

2d. With reſpect to the low grounds laying upon the *Till*, the *Foſſdyke* water being raiſed 10 inches by the ſtanches at *Lincoln High Bridge*, will pen 10 inches upon the mouth of the ſaid river in dry ſeaſons, at which time it has no currency; but as we don't find any of thoſe grounds will be affected thereby, except the ſmall quantity before ſpecified, and as in times of rains and floods, or whenever the water coming from the *Witham* would, in its preſent condition, riſe 10 inches above its loweſt ſtate, (which, as has been ſhewn before, is the greateſt part of the year) the *Till* will have a much better out-fall than it now has; for, in the firſt place, as the *Witham* waters (which at preſent riſe upon them near 4 feet in times of floods) will be entirely ſhut out from the *Foſſdyke* whenever they would over-ride the ſame, by reaſon of the lock near *Brayford Meer*, and banks mentioned in the 5th article, as thoſe waters themſelves will be much ſooner diſcharged than at preſent by the propoſed ſtanches, as the gauge bar at *Torkſey Lock* will be removed; and as it is alſo propoſed to confine the flood waters of the *Till* with banks of a ſufficient height and ſtrength to ſuſtain them till they are fully diſcharged into the *Foſſdyke*, the low grounds on each ſide the ſaid *Till* can then be no otherwiſe annoyed than by the down-fall and ſoakage waters, which will be very inconſiderable, as the earth for making the ſaid banks is of a ſtrong and tight texture, and as an ample proviſion for carrying off theſe down-fall and ſoakage waters is made by the ſubterraneous tunnel to be laid under the *Till* into *Burton Drain*, it follows, that upon the whole, the diſcharge of the *Till* waters will be conſiderably facilitated and improved, and the drainage of the low grounds under conſideration, that lay thereupon, will be compleated.

3d. The grounds, weſt of *Saxelby*, which drain into the *Foſs*, will in like manner have the ſurface of that river raiſed 10 inches upon the tail of their drains, in dry ſeaſons; but as we find none of them that will be affected by that riſe, (very little by double, nay even treble) and as the *Foſs* will no longer be raiſed by the *Witham* floods, and thoſe floods ſooner run off by the gates of the propoſed ſtanches, it will be kept at a more conſtant height, being no otherwiſe affected than by the influx of their own and the *Till* waters, which will find their way either into the *Trent* or *Witham* waters, as ſoon as either river is ſo ſettled as the *Foſs* water will over-ride them; ſo that upon the whole,

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thefe lands being freed from the high floods, which principally annoy them, will be greatly benefited, and ought in ftrictnefs to contribute towards the making of the faid lock and bank.

4th. The proprietors of lands above *Brace Bridge* will alfo receive benefit by this conftruction; for fince there is 18 inches fall from the upper mouth of *Sincil Dyke* to *Brayford Meer* at ordinary feafons in fummer, it is plain that an additional pen at the faid meer will not fenfibly affect the level of the water at the entrance of *Sincil Dyke*; on the contrary, when the widening and deepening of the River between *Brayford Meer* and *Brace Bridge* is performed, the water will then run off lower than at prefent; and fince the tops of the ftaunches at *Sincil Dyke* and one of the *Gowt Bridge Drains* are to be lower than their refpective bottoms now are, and the capacities of thofe drains greatly enlarged, it is manifeft that though the ftaunches were never to be drawn at all, the water would have a better paffage than it can now have; but as the prefervation of the banks, propofed in Article 5. of the fcheme, depends upon drawing the ftaunches, the proprietors of the aforefaid low grounds will not be wanting in drawing them when neceffary, which will afford a great eafement to the paffage of the water far beyond any thing they have ever had: and, for the prevention of difputes between the land owners and navigators, it is propofed that whenever the water of *Brayford Meer* covers the ftone pillars propofed in Article 10. that the gates of the ftaunches fhall be drawn, or fo many and fo much as fhall be found neceffary to reduce the waters 1 inch below the top to the mark aforefaid; and whenever the water fhall fettle below the faid mark, then the gates of the faid ftaunches to be fhut down, or fo many and fo much as to prevent its falling below the faid mark, which bufinefs will be regularly done by a perfon properly appointed and authorized for this purpofe.

5th. The undertaking for drainage of the fens, and navigation between *Lincoln High Bridge* and *Bofton*, will alfo be benefited by this fcheme; for fince the great object of that fcheme was to preferve the living and flood waters, particularly thofe of the *Witham*, for fcouring of the out-fall, by this means they will be preferved, and brought down by the readieft paffage, inftead of being fpread over the fens and low grounds above *Lincoln*, by which their force is broke, and a great part thereof evaporated by the fun and winds. It is true that the *Foffdyke* being kept up 10 inches higher, will expend fomewhat more water in the paffage of each veffel; but, on the other hand, the communication between the *Foffdyke* and the *Swan* and *Cuckoo Pools* being ftopped, the evaporation from the extended furface thereof will thereby be faved; and the matter being reduced to a fair calculation, it appears that this evaporation is greatly more than fufficient to

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ſupply the difference of lockage, leakage, and ſoakage, that will probably ariſe from an increaſe of height of 10 inches in the *Foſſdyke* ſurface.

6th. This ſcheme will alſo be of great benefit to the navigation of the *Foſſdyke*, not only in giving the neceſſary quantity of water to render it compleat in all ſeaſons, from the river *Trent* to *Lincoln High Bridge*, but in excluding ſuch extra quantities of water, as in time of floods not only annoy the navigation, but the lands adjoining thereto, which inconvenience muſt have ſubſiſted ever ſince this cut was originally made, and conſequently muſt always have been the foundation of diſputes and diſſatisfactions between the navigators and land owners thereto adjoining; and upon the preſent ſcheme it appears that the intereſt of both parties coincide, it is greatly to be wiſhed and hoped that they may as heartily join in the expence of executing the ſame upon an equitable footing; and leſt any jealouſy on the part of the land owners ſhould obſtruct the execution of a project ſo much to their advantage, as ſuppoſing it more calculated to ſerve the navigation than themſelves, we think it expedient to declare, that nearly the ſame advantages can be procured to the navigation as will be obtained in the ſcheme before ſpecified, without prejudice to the preſent ſtate of the land owners drainage, and that to accompliſh as good a drainage, as is propoſed by this ſcheme, will coſt the land owners conſiderably more, than if done conjunctly with the proprietors of the navigation.

An ESTIMATE of the works mentioned in the preceding ſcheme.

	£.	s.	d.
Article 1ſt. To making good both banks of the *Foſſdyke*, from *Brayford Meer* to *Saxelby Paſture*, oppoſite the *Till*, - - - - - - -	463	15	0
Art. 2d. To ſcouring out and enlarging *Sincil Dyke*, from its lower mouth to the firſt *Gowt Bridge Drain* (including contingencies), - - - - -	172	15	8
To ſcouring out the firſt *Gowt Bridge Drain*, from *Sincil Dyke* to the *Witham*, and the contingency of under-pinning the arches under which it paſſes, -	53	0	0
To making and laying the fox under the *Witham*, - - -	208	12	0
To making a new drain from the fox to *Swan Pool*, - - -	63	2	0
To making a drain from *Swan Pool* to *Cuckoo Pool*, - - -	84	0	0
Art. 3d. To making a new drain from or near *Swan Pool* to *Biſhop's Bridge*, - -	145	4	0
Carried over	1190	8	8

To

	£.	s.	d.
Brought over -	1190	8	8
To making and laying the fox under *Foſſdyke*, - - - - -	190	0	0
To making a new hauling bridge over the drain, and a waggon bridge for the road to *Pywipe* inn, - - - - - - -	40	0	0
Art. 4th. To conſtructing a lock between Mr. *Elliſon*'s wharf and *Brayford Meer*, -	400	0	0
Art. 5th. To ſcouring out and enlarging the river *Witham*, and embanking the ſame on the weſt ſide from *Brayford Meer* to *Brace Bridge*, and to embanking *Brayford Meer* on the ſouth-weſt ſide, from the north end of the aforeſaid bank to the lock, and from the lock acroſs the high land in the north, including the ſouth drain, - -	587	19	0
Art. 6th. To ſcouring out and enlarging *Sincil Dyke*, between the lower mouths of the *Gowt Bridge Drain* - - - - - - -	12	0	0
Scouring out and enlarging *Sincil Dyke* from the ſecond *Gowt Bridge Drain* to the *Witham*, and the contingence of under-pinning Bargate bridges, - -	63	5	0
To ſcouring out and enlarging the ſecond *Gowt Bridge Drain*, from *Sincil Dyke* to the *Witham*, and the contingence of under-pinning the arches under which it paſſes,	42	10	0
To erecting two ſtanches, one at the upper mouth of each of theſe drains, at 180*l*. each,	360	0	0
Art. 7th. To conſtructing a fixed ſtanch, with draw-door, at or near the *High Bridge*, at *Lincoln*, - - - - - - - - -	200	0	0
To ſcouring out *Brayford Head*, and deepening the river from *Brayford Meer* to *Lincoln High Bridge*, including the rebuilding of walls, - - - -	195	0	0
Art. 8th. To deepening and enlarging the *Till*, from *Haddow Bridge* one mile upwards, ſo as to be 12 feet wide at the bottom, and making ſtrong and effectual banks on each ſide, at leaſt five feet above the low water in the *Foſſdyke*, - - -	168	6	0
To making and laying a ſubterraneous tunnel under this dyke and banks, 6 inches ſquare within, - - - - - - - -	4	0	0
To making a catch-water drain and bank on the lower ſide, at the upper end of this new cut, to reach the high land on each ſide the ſame, which will conduct all the flood-water therein, - - - - - - -	8	5	0
Art. 9th. To taking away the gauge-bar at *Torkſey Lock*, - - -	0	5	0
Art. 10th. To erecting a ſtone pillar for a gauge height in *Brayford Meer*, - -	5	0	0
Art. 11th. To ſuperviſing, and unforeſeen contingencies, at 10*l*. per cent. - -	350	0	0
£.	3816	18	8

Doncaſter, October 16, 1762.

JOHN GRUNDY.
J. SMEATON.

We come now to give an anſwer to the following queſtion, communicated to us by Mr. AMCOTTS.

" Mr. GOLLMAN deſires to know if the *Sincil Dyke* and the *Gowt Bridge Drains* " were to be ſcoured out and deepened to the depth of the new intended river below " *Lincoln*, with gates erected at the upper end 2 inches higher than the preſent height of " *Brayford Head*, a channel to be made from thoſe places into *Brayford Meer*, to com- " municate with the *Foſſdyke*; the gates to be opened at the time of floods, the ſhoal at " *Brayford Head* to be removed, and gates or a ware to be erected by the ſide; the top " of which to be 10 inches lower than the preſent height of *Brayford Head*, with a waſte " board to be placed thereon in dry ſeaſons; what effect ſuch a ſcheme would have on " the *Foſſdyke* navigation?" The ſcheme here propoſed, in ſome reſpects, is the ſame as the ſcheme propoſed by us, as before ſpecified, but with this eſſential difference, that our ſcheme propoſes to give the *Foſſdyke* navigation an addition of 10 inches conſtant water above its loweſt ſtate, and a compleat drainage to the lands; the other to keep it conſtantly at its loweſt ſtate, with an imperfect drainage of the lands.

From the time the rains uſually fall in *September* or *October*, to the running off and evaporating the flood waters in *May*, the *Foſſdyke* navigation is generally as compleat as can be wiſhed for; but were the flood waters run off by the propoſed gates as they come down, the *Foſſdyke* would never be above its loweſt gauge, except at the top of high floods; which, as they would be uncertain, would be of little uſe to the navigation: for as *Brayford Head* is propoſed to be reduced 10 inches, except in dry ſeaſons, this would conſtantly run off the common current waters; and perhaps often more than that after the gates had been drawn, ſo that at thoſe times the *Foſſdyke* would be reduced to a lower ſtate than it ever can be at preſent, all which in conſequence would be a great detriment thereto; beſides, no man as a navigator would chuſe to ſubject his water to the mercy or miſconduct of others, or the want of neceſſary repairs of gates, ſtanches, or other works, without any proſpect or probability of any advantage ariſing therefrom.

And with reſpect to drainage, the ſcheme propoſed by the aforeſaid queſtion is extremely imperfect, almoſt all the requiſites for a compleat one being omitted, that is to ſay, the neceſſary imbanking of the rivers, &c. to keep out the flood and barrier waters, and the proper means of carrying off the downfall and ſoakage to a ſurface ſufficiently below the ſoil of the lands to be drained; for nothing more is thereby propoſed towards accompliſhing theſe great ends, than forming ſtakes to eaſe the flood waters, (which is as fully and amply provided for in our ſcheme as in this) but very far from totally re-

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moving their effect upon the low lands in question; so that, after the execution of such a plan, the low grounds of *Boatham*, *Skellingthorpe*, *Saxelby*, *Lincoln*, *Burton*, *Carlton*, &c. would yet be liable to be overflowed in all wet seasons, and in dry ones the proposal itself points out no advantage in drainage.

JOHN GRUNDY.
Doncaster, Oct. 16, 1762. J. SMEATON.

Concerning the drainage of the low grounds of *Torksey* and *Fenton*, which drain by *Torksey Bridge Sluice*.

AS the drains of those grounds have no communication with the *Fossdyke*, till below *Torksey Lock*, their out-fall is in effect into the *Trent*, and therefore it is of no concernment to them what the height of the *Fossdyke* surface is between *Torksey* and *Lincoln*.

Torksey Bridge Sluice (the out-let) lays on the south side of the *Fossdyke*, and also the drain leading thereto, which extends eastward about a furlong, and there divides, one branch turning to the right through *Fenton Moor*, the other to the left through *Torksey* low grounds, which laying on the north side of the *Fossdyke*, communicates by means of a subterraneous tunnel or fox, each drain having a separate sluice near the point of partition, which shuts reciprocally in case either water should over-ride the other. Each of these drains receives the down-fall waters from an extensive tract of country, and in consequence, in times of great rains, when the *Trent* is so full as to keep shut the doors of *Torksey Bridge Sluice*, those waters overflow their respective drains, and consequently the lowest lands near their out-fall, and if the rains are violent and lasting, and the *Trent* continues high, as it sometimes does for weeks together, the waters, all this while accumulating within, rise to a great bulk and height. As therefore the cause must always remain, the effect will do so too; the only thing that can be done, in the present case, is to give the water a passage sufficiently free, that whenever the *Trent* becomes lower than the waters within, they may run off as soon as may be. Those ought to be the views of them who undertake the drainage of those tracts of land. The only question that relates to the *Fossdyke* is, whether the proprietors thereof have made provision for dis-

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charging thofe waters as amply as the proprietors of lands have made for themfelves to bring the water thither *.

The fluice at *Torkfey Bridge*, and the fox under the *Foffdyke*, are works conftructed by the undertakers of the *Foffdyke*; the fluice at the tail of *Fenton Drain*, and that at the tail of *Torkfey Drain*, leading into the fox, are old works conftructed by the land owners to ferve their own occafions. The fluice at *Torkfey Bridge* confifts of one arch or tun of 7 feet wide, which having a ftaple-poft of 1 foot wide in the middle, forms it into 2 apertures of 3 feet wide each, which are fhut by two falling doors; the floor of this fluice lays lower than *Fenton Sluice* by 1 foot 9 inches, lower than the fluice entering the fox by 1 foot, and lower than the loweft lands to be drained thereby 2 feet 1 inch. The width of *Fenton Sluice* is 2 feet 11 inches; the fluice leading to the fox confifts of two doors, which are 2 feet 1 inch wide each. The width of the fox is 2 feet 10 inches by 2 feet high, and the entry thereof lays 8 inches lower than the threfhold of the fluice adjoining. 1ft. The queftion is therefore, whether *Torkfey Bridge Sluice* is equal to the capacity of *Fenton* and *Torkfey Fox Sluice* taken together, in point of difcharging water; and, 2d, whether the capacity of the fox is equal to the capacity of the fluice leading thereto. Having fubjected this matter to calculation, we find that at a mean height of the flood waters upon *Torkfey* (which is the loweft lands) that *Torkfey Bridge Sluice* will run more water than *Torkfey Fox Sluice* and *Fenton Sluice* put together, by above 200 cube feet in a minute, which arifes from its laying fo much lower; but that, in the like cafe, the fox will not run fo much water as the fluice adjoining thereto; but that if another equal tunnel is thereto added, that the capacity of the two will exceed the capacity of the faid fluice by above 500 cube feet in a minute. We therefore recommend it to the *Foffdyke* proprietors to add another fox of equal capacity, or to double the capacity of the prefent; but as we are of opinion the foundation of the grievance does not fo much confift in want of capacity in the fox to difcharge the water, as in the fluice itfelf to run it off, *low enough*, we are of opinion, that at the fame time the capacity of the fox is enlarged, that the land owners fhould lay the threfhold of this fluice as low as the out-fall fluice at the bridge, and that the entry into the fox fhould be made conformable thereto. In this cafe, the mean capacity

* In conftructing works by act of Parliament, if ample provifion is made for the prefervation of private property, to the fatisfaction of the proprietors at the time, that if afterwards thofe proprietors extend their views in order to improve their property, that the public undertakers at their own expence to make all fuch alterations in their works that the land-owers fhould think fit; if this was the cafe, a public undertaker would never know when he had done.

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for difcharging water will not only be doubled, but with the advantage of running it 1 foot lower than at prefent, which will be above 2 feet lower than the loweft lands that drain thereby.

N. B. It muft, however, be confidered, that it is but lately that a new tunnel of 2 feet wide at *Harrow Head Bridge* has been added; the whole capacity of that bridge was before that time only one tunnel of 2 feet 2 inches wide, the paved floor whereof lays at leaft fix inches higher than the fluice at the fox; and as the bulk of the water that comes to that fluice comes through this bridge, it muft be acknowledged that the capacity of the fox to difcharge water at the time it was made was fuperior to the capacity of this bridge to let down the water to it.

The meeting of the *Torkfey* and *Fenton* waters, in a direction nearly oppofite, is a manifeft incongruity; but as the place of meeting is pretty deep, and wider than the reft, it forms in fome meafure a refervoir common to both, and, if perfectly fo, it would fignify little in what direction the water comes in; but as it appears to us, that as the land drains and fluice lay lower on the *Torkfey* than on the *Fenton* fides, that the *Fenton* waters will generally over-ride the *Torkfey*: this will deferve a remedy that will alfo cure the other defect at the fame time. We therefore propofe that a new tun of 4 feet wide and 3 feet high, with one door, to be added to the prefent fluice at *Torkfey Bridge*, on the fouth fide thereof, and making a partition between the old and new tuns, and to bring the prefent common drain in an oblique direction to the new tun, and to carry a new drain from behind the faid partition, from the old fluice to the tail of the fox, ftopping the prefent communication near *Fenton Sluice*; by thefe means the waters will be kept quite feparate, which will be a great improvement to the prefent drainage of the low grounds under confideration; and as it will lay the foundation for compleating the drainage thereof, as far as nature will allow, in our opinion, the land owners ought to be at part of the expence of the aforefaid new fluice and drain. An obvious miftake has alfo been committed in turning the tail drain leading from *Torkfey Bridge Sluice* into *Fofs*, below the lock, at a fquare elbow; but if it be confidered, that this drain, being wider than the clear water-way of the fluice by three feet, and deeper than the floor thereof, the velocity of the water is fo much lefs on account of a greater capacity, that the ill effect of this inconfiftency is not, in reality, fo great in the prefent cafe as it may feem; however, as this drain muft be widened near the fluice, on account of the new tun, to give a freer paffage to the water, and to remedy this defect both at once, we advife the turn of the faid drain to be made by a quarter round inftead of a fquare elbow.

JOHN GRUNDY.

Doncafter, October 16, 1762. J. SMEATON.

To the gentlemen assembled at a general meeting on the 2d day of September, 1782, for considering of a plan of improvement of the navigation of the river *Fossdyke*, and for improving the drainage of the lands on each side the said river.

GENTLEMEN,

SINCE my arrival at *Lincoln* on Thursday evening last, (as desired by Mr. LYON) I have diligently employ edmyself, in conjunction with Mr. CARLTON, and Mr. PILLEY, agent for Mr. ELLISON, who were appointed to conduct me, in reviewing the different parts of the extensive scheme of drainage and navigation, that was formed by Mr. GRUNDY and myself in the year 1762, in order to prepare myself to assist you, gentlemen, in the reconsideration thereof.

It is a subject indeed so extensive, that the time has been fully employed in going over some of the most material and leading parts thereof, and it will necessarily take a further length of time to enter into that accurate and digested consideration that it had from Mr. GRUNDY and myself at the time abovementioned, being now 20 years ago. But, as upon this revisal, I find a very striking difference in the situation of the leading circumstances attending this business, I think it necessary to lay those open to your consideration, because, unless some means are found, by which the impediments, that since that time have been placed in the way, can either be removed or avoided, it seems fruitless to enter into any scheme for the general drainage of the low grounds west of *Lincoln*: for it does not appear to me, that as things now stand, any such material improvement can be made therein, as shall be likely to answer the cost of doing it.

When the scheme of 1762 was under consideration, the *Witham* navigation act from *Lincoln* to *Boston* was then subsisting, with a clause therein, that no staunch or land-door should be erected between *Washingborough Ferry* and *Lincoln High Bridge*, which should not be at least 2 feet below the lowest grounds in *Canwick Ings*, as by reference to the act will more fully appear. At present, I find a lock and a staunch below the lower mouth or out-fall of *Sincil Dyke*, which by the former scheme was to be the out-fall of the drainage waters of the lands west of *Lincoln* into the river *Witham*, the top of the gates or doors of which staunch is higher than the surface of the said lowest grounds of *Canwick Ings*, and consequently they are, as it appears to me, full 2 feet higher than according

according to the ſaid clauſe they ought to be, (the doors or gates of the lock being ſtill higher) and the top of the gates or doors of the ſaid ſtaunch being full as high as *Brayford Head* was in 1762. The fall for the drainage waters from *Brayford Meer* to the lower mouth of *Sincil Dyke* is now taken away and loſt, the water being now ſo near upon a level at the two ſaid points, as to be totally inſufficient towards any material improvement in point of drainage.

In order, therefore, to recover the fall for the propoſed drainage waters that then ſubſiſted, it appears to me abſolutely neceſſary, either to remove the ſaid ſtaunch, whereby the waters may have their natural deſcent in its ancient courſe through the city of *Lincoln*, or to carry the out-fall drain ſo far below the limits of the *Sincil Dyke* as to paſs through ſome part of *Canwick Ings*, and fall into the preſent courſe of the river *Witham* below the ſaid lock and ſtaunch; that is, where the ſame, on mature conſideration, ſhall be deemed the moſt eligible.

The latter way appears to me at preſent preferable, not only as it would not interfere with the preſent navigation, but the drainage waters would be leſs liable to be over-rode by the living waters of the *Witham*.

I am, Gentlemen,

Your moſt humble ſervant,

Lincoln, September 2, 1782. J. SMEATON.

To the Gentlemen that attended a general meeting on the 2d day of September, 1782, at the *Rein Deer* at *Lincoln*, for considering of a plan of improvement of the navigation of the river *Fossdyke*, and for improving the drainage of the lands on each side of the said river.

The REPORT of JOHN SMEATON, Engineer, upon the improvement of the navigation of the river *Fossdyke*, and for improving the drainage of the low lands on each side of the said river.

IN the year 1762, Mr. GRUNDY and myself were employed by Mr. ELLISON to form a scheme for the improvement of the *Fossdyke* navigation, and at the same time to improve the drainage of the low grounds west of *Lincoln*, of which business we acquitted ourselves by our joint report, dated the 16th of October of that year; contrariety of opinion among the parties interested at that time prevented the execution of the scheme then proposed.

In August last I was invited to reconsider the said scheme, and to assist the gentlemen interested in this business in forming such a one, as at this time should be useful and agreeable to all parties, and to attend their public meeting at *Lincoln* for that purpose upon the 2d of September last, which accordingly I did.

On reviewing the subject previous to this meeting, I perceived that upon supposition of the best possible drainage, compatible with the improvement and even *subsistence* of the *Fossdyke* navigation, that the scheme then proposed appeared now to me to be very complete upon the circumstances and situation in which things then were; but that at present, the case is so very much altered, that the very ground and foundation upon which we built the principal merit of the scheme, so far as it related to drainage, is now subverted; for the ultimate drainage of all the grounds in question being into *Brayford Meer*, and as at that time there subsisted a fall in dry seasons in summer from *Brayford Meer*, through the city of *Lincoln*, to that part of the river *Witham* where the tail of *Sincil Dyke* falls into it, of 14 inches, and a further fall then of $5\frac{1}{2}$ inches more to *Stamp End*, and which was still greater down to the point where *Bailey's Sluice Drain* falls into the same, it appeared to us, that the addition of this fall to the low grounds that then drained into *Brayford Meer*, when judiciously managed, would make the drainage thereof very compleat. Nor were there at that time any reason to fear the loss of this fall, but

rather an expectation of gaining more; for though the act of parliament for draining the lands, and making or improving the navigation from *Lincoln High Bridge* to *Boston*, had then passed; yet as the advantages that might in future possibly result from this fall to the city of *Lincoln*, and low grounds west thereof, were guarded by a clause, enacting that no staunch or land door should be erected between *Washingborough Ferry* and *Lincoln High Bridge*, which should not be at least 2 feet lower than the lowest grounds in *Canwick Ings*, there could then, in regard to this fall, be no apprehension of difficulty; but contrary thereto, on this view I found a lock below *Stamp End*, now called *Lincoln Lock*, accompanied with a staunch, erected across the river *Witham*, abreast of the said lock, and consequently below the tail or out-fall of *Sincil Dyke*, into the said river; the top of the said doors of which staunch was not only higher than the medium surface of the lowest grounds in *Canwick Ings*, and therefore full 2 feet higher than according to the said clause they ought to be, but also higher than the natural staunch of *Brayford Head* was in the year 1762, and occasioned a pen of the water in *Brayford Meer*, higher by 1½ inch than it was at that period: in consequence, as in this state of things *Brayford Meer* is rather higher than lower than it was, and the fall that might have been required totally taken away and destroyed, it follows, as things now are, (*Brayford Meer* being still the ultimate out-fall of the drainage of all the lands in question) that no material improvement can be made therein.

These consequences I did myself the honour of laying before the gentlemen assembled at the meeting of the 2d of September last, and withal observed, that unless either *Lincoln Lock* and *Staunch*, as it now stands, can be removed, or a new out-fall procured for *Sincil Dyke*, so as to fall into the *Witham* below the said staunch, it will be to no purpose to think of any schemes of drainage that will be likely to be attended with benefit equal to the expence.

These matters being fully considered by the gentlemen present, and seeing difficulties in either way, and it being the general sense of the meeting, that it would be a considerable improvement to their low grounds, if they could more early in the spring be cleared and ridded of their water, without destroying the navigation through *Lincoln*, I then observed, that on supposition *Lincoln Staunch* and *Lock* was removed still higher up the stream from its present place, above the tail of *Sincil Dyke*, I did not doubt but to be able to draw up a scheme that would not only preserve, but greatly improve the navigation through *Lincoln*, greatly benefit the drainage of the lands without imbankments upon the *Witham*, but also give every competent improvement to the *Fossdyke* navigation, and that by expedients to which I could not see any reasonable objection.

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This ſcheme, after fully and deliberately conſidering, I now beg leave to propoſe.

The lands at preſent under conſideration are the general reſervoir of the waters that in great floods are brought down by the river *Witham* from the upland country, through a courſe of above 40 miles, the paſſages for which through *Lincoln*, relative to the fall it has, are at preſent ſo very inadequate to the diſcharge of this water as faſt it comes, that it extends over a vaſt tract of ground of many miles ſquare.

In the year 1762 it was known to have roſe above its ſummer drainage height about 4 feet perpendicular, but upon this view this water, from marks that were ſhewn me, its height had been more than 5 feet 9 inches above the former mark, which ſhews that the banks neceſſary to reſtrain and carry off ſo great a body of water as faſt as it comes would be required of ſuch heighth and ſtrength, that I am of opinion (with the land owners) it would be not only very difficult and very expenſive to confine, but be matter of objection to the drainage of the lands upon the *Witham* below *Lincoln*.

In a dry ſeaſon the lands in queſtion become compleatly drained by the preſent outlets, but as the ultimate level of *Brayford Meer*, at which the freſh waters of the *Witham* can be diſcharged, is but a few inches lower than the loweſt grounds propoſed to be drained, when the top waters are ſo much run off, as that the drainage is almoſt compleated, the quantity capable of being then diſcharged but ſo little exceeds the influx of the *Witham* from the higher country, that was it not for the joint action of the ſun and winds, the ſurface of theſe loweſt tracts would never become dry, ſo as to be capable of any good produce of vegetation; but if when the top waters are run off, and the whole ſurface reduced to the level of the preſent natural banks of the river and aqueducts, a diſcharge is provided, that now cannot run for want of level or fall, a very moderate diſcharge (that would ſignify but little in reſpect to the running off of the top waters) continuing to operate by itſelf ſeparately, and independently of the river *Witham*, and appropriated wholly to the diſcharge of ſuch internal waters as are left behind, after the flood waters are reduced within their natural banks; I ſay, ſuch internal dead waters would very ſpeedily be diſcharged when all communication with the living waters were cut off, though this new and ſeparate diſcharge was not above half as much as the current of the river *Witham* in dry ſeaſons.

It is obvious, that a meer removal of *Lincoln Lock's* ſtaunch would not fully effect this buſineſs, even though *Brayford Head* was fully cleared, and the channel deepened through *Lincoln*, becauſe ſtill the *Witham* water would be obliged to paſs through the

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ſame channel; that is, it would paſs through the preferable channel, in point of fall, while in common, and therefore would interfere with and over-ride the drainage waters at the very pinch when the drainage was wanted to be compleated.

Furthermore, if the *Foſſdyke* navigation was ſupplied with water by an aqueduct from an higher part of the river *Witham*, independent of *Brayford Meer*, and the out-lets of all ſuch grounds as drain into *Foſſdyke* eaſt of *Saxelby*, or into *Brayford Meer*, banked off, (making *Foſſdyke* itſelf a means of diſcharging the top waters when the whole country is over-preſſed) then *Brayford Meer* may remain at its preſent height, and all impediments be removed between *Brayford Meer* and the firſt lock towards *Boſton*, as low as to the floor of the water-way under *Lincoln High Bridge*, which would render the navigation through *Lincoln* much preferable to what it now is, as there would be 2 feet depth of water at ſuch times and places where now there is no more than one.

THE SCHEME.

1ſt. To remove the lock called *Lincoln Lock* and its ſtaunch, from its preſent place below *Stamp End*, to above the tail of *Sincil Dyke*, where there is a commodious opening to receive it, as will appear from a ſketch of the manner in which it may be placed.

2d. To deepen that part of the river *Witham* that lays between the preſent place of the ſtaunch, and the place where it is now recommended, ſo as to make it paſſable for any boats that can now come up to *Lincoln Lock*, and which will not require a deepening of above half a foot at a medium.

3d. To ſcour out *Sincil Dyke* to as great a width as it has ever originally been, from its tail or out-fall into the *Witham*, to the tail of the great *Gowt Drain*, bringing up its bottom upon the ſame dead level with the bottom preſcribed in the laſt article, as neceſſary for navigation, and to as great a width as it will carry, after allowance of ſufficient ſlopes.

4th. To dyke and ſcour out the great *Gowt Drain* to the greateſt width it will bear, and ſtill bring up the bottom upon the ſame dead level as preſcribed for *Sincil Dyke*; but inſtead of opening a communication with the river *Witham*, to continue the ſaid drain under the river by means of an under-ground tunnel four feet wide and four feet high clear water-way, with doors pointed towards *Sincil Dyke*. The floor of this tunnel to be laid ſo much deeper than the bottom of the *Great Gowt Drain*, that the river *Witham* may run in its

its present natural courfe above its arch, and that the work of the faid arch be finifhed as high as that the river *Witham* may pafs over it without raifing its furface, in its ordinary or extraordinary ftate, upon a width of at leaft 30 feet. The weft fide wall next the low lands to be raifed to a competent height to prevent the *Witham*'s waters, in time of floods, from cafcading over it; but the height of the eaft wall to be raifed only one foot above the ordinary furface of the *Witham*, fo that when there is a fwell in the *Witham* above that height, it may cafcade over into this *Gowt Drain*, which will then act as a flaker, according to its prefent intent, and make its way by *Sincil Dyke* to the *Witham*.

5th. To fcour out *Sincil Dyke*, from the tail of the *Great Gowt Drain*, to its upper mouth at the river *Witham*, yet not to make an open communication with the river; but to prevent the river in dry times from taking its courfe that way, and to give it a competent paffage through *Sincil Dyke* as a flaker drain, (to which ufe it has been apparently intended in its original formation) to conftruct a weir of 60 feet in length upon the crown, ranged along the eaft fide of the river *Witham*, which, being immediately collected into *Sincil Dyke Drain*, can run no more water in high floods than the drain will and ought to contain: in time of dry feafons to be about one inch above the water's furface of the river, fo as juft to pen in all the water thereof, and upon a frefh rifing above that to difcharge a competent quantity, upon a moderate additional height, in virtue of the length of its crown.

6th. To effectually fcour out the leffer *Gowt Drain*, and in like manner as the entry into *Sincil Dyke*, to be fhut off by a weir of 45 feet long in the crown, conditioned and operating as *Sincil Dyke* in proportion to its fize; but to allow for the natural fall of the river from *Sincil Dyke* to the entry of the little *Gowt Drain*, this weir to be gaged $1\frac{1}{2}$ inch lower than the former. And N. B. it will be proper to give all poffible freedom and effect to thefe 2 flaker drains, becaufe the *Great Gowt Drain* will not now ferve this purpofe except in floods.

7th. A drain to be carried from the faid tunnel, at the head of the *Great Gowt Drain*, to *Swan Pool*, and to pafs by or through the fame, as fhall be found moft convenient and practicable in the execution; to be of 12 feet bottom, with proper flopes, and ftill carried on upon the fame dead level. From thence the drain to pafs forward upon a 10 feet bottom to a proper place, to divide into two branches; one tending towards *Cuckoo Pool*, and the interior parts of *Skellingthorpe*; the other towards a proper point of the *Foffdyke*, to receive the *Burton* and *Carlton*, &c. waters, from *Bifhop's Bridge*, by a fubterraneous tunnel under the *Foffdyke*; all which faid drains are to be carried on upon the fame dead level as before prefcribed.

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8th. A ſubterraneous tunnel to be laid under the *Foſſdyke*, to communicate the water from *Biſhop's Bridge*, of ſufficient capacity to run the drainage waters without material loſs of fall after the top waters are diſcharged; but as the laying a tunnel of this kind, the top of whoſe arch muſt be ſo deep below the common ſurface of *Foſſdyke* as to clear the navigation, the conſtruction of ſuch a tunnel by the ordinary means in brickwork would require ſo much length of time as to be a great loſs of tolls to the navigation, which, together with the actual expence, would lay too great a burthen upon the ſcheme I am propoſing; I would therefore recommend the tunnel under the bottom of the navigable river to be made of caſt iron. This to be made in proper lengths with flanches, by which they can with bolts be readily joined together; and I expect that a clear iron pipe of 2 feet 6 inches diameter would be very competent to this buſineſs, but that of 3 feet would put it beyond all doubt.

9th. From this tunnel a drain ſhould (ſtill upon the ſame dead level bottom) be carried to *Biſhop's Bridge*, and that bridge rebuilt correſpondent to ſuch depth, the width of the drain's bottom to be 9 feet, and the tunnel of the bridge correſpondent; from thence the drain to be carried forward, as a private work, into *Burton* and *Carlton* lordſhips; but ſtill I would recommend, that whatever width may be taken for the bottom, that it be carried on upon the ſame dead level till it comes to the pinch of that drainage, which, according to Mr. GRUNDY, is in *South Carlton* lordſhip, and that the ground in the loweſt ſlade there is no more than $14\frac{2}{10}$ inches above *Brayford Head*, as in the year 1762, that is $8\frac{2}{10}$ inches above *Brayford Meer*, as I found it this year, 1782; from thence the main drains, as well as ſide drains bottoms, may be allowed to riſe at diſcretion.

10th. I would recommend a drain to be continued from the former, at or near *Cuckoo Pool*, through *Skellingthorpe*, by way of the low ſlade of the ancient courſe of the *Till*, into *Saxelby Paſture*, till oppoſite *Saxelby Meadow*, on the north ſide of the *Foſſdyke*, diminiſhing from a 7 feet bottom at *Cuckoo Pool*, to a 5 feet bottom at the ſaid point in *Saxelby Paſture*; but ſtill continuing the ſame dead level.

11th. Between Mr. *Elliſon*'s wharf and *Brayford Meer* to conſtruct a navigation lock, with gates pointed towards the *Foſſdyke*, ſhutting up all other communication between *Foſſdyke* and *Brayford Meer*, except by a weir, as per next article.

12th. To make an aqueduct of 10 feet bottom, to take its water at the river *Witham*, juſt above the *Great Gowt* drainage-tunnel, and to paſs to the *Foſſdyke* at ſome

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convenient place oppofite to or weft of Mr. *Ellifon*'s wharf, in order to fupply the *Foffdyke* with water; and, at a certain height, a weir or over-fall to be conftructed, that all redundant water beyond the fupply of the *Foffdyke* navigation may be returned into *Brayford Meer*, and fo go to *Bofton*; this ought to be 40 feet in length upon the crown.

N. B. This aqueduct neceffarily interfecting the drain prefcribed in the 9th Article, is to pafs it, by a continuation of the tunnel, as an aqueduct bridge, to convey its water in a feparate paffage over the drain, and to be well imbanked on each fide, fo that it be never overflowed till the country is under water.

13th. To make a provifionary navigable ftaunch at *Brayford Head*, the gates whereof to be gauged to the fame height that *Brayford Head* was in 1762, that the navigation into and upon *Brayford Meer* may not be dependant upon the ftaunch at *Lincoln Lock*, and the whole paffage cleared from *Brayford Meer* to *Lincoln High Bridge*, as deep as the floor of the paffage of the faid bridge; and then if the truftees for the navigation from *Bofton* to *Lincoln* think proper, in like manner, to clear away to the fame depth eaft of the faid bridge, there will be a clear navigation from *Brayford Meer* to the fea, equivalent in all parts paffing *Lincoln* to that under *Lincoln High Bridge*.

N. B. In time of floods the gates of the *Brayford Head* ftaunch muft be fet open, as well as the doors of the *Lincoln Lock* ftaunch, for relief of the country weft of *Lincoln*, in running off their top waters, as I am informed is very properly the prefent practice; but it fhould feem that the opening and fhutting of thefe doors fhould be within the direction of the magiftrates of the city of *Lincoln*, who, being moft central, will more readily be apprifed of, and fee the neceffity of the country.

14th. That for the general relief of the country weft of *Lincoln*, and the more fpeedily to get rid of their top waters, which, as before, will continue to overflow the whole Country in the winter feafon, it will be very proper to embrace Mr. ELLISON's propofition of granting liberty for a fide weir to be conftructed of a proper height at *Torkfey*; fo that a part of the top waters may be run that way into the *Trent*, when the level of the *Trent* will admit thereof, as it often at fuch times does. This weir, however, fhould not be too low, that the *Witham* fens drainers may have no reafonable complaint of lofing water to keep their out-fall clear; nor fhould it be too high, becaufe, if fo, it will be of little ufe in anfwering the purpofe for which it is made; but it fhould be of confiderable extent in length upon the crown, that when it does difcharge it may do it with effect. It appears to me, that if it is made 100 feet upon the crown, its height 6 inches below the

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gauge bar of *Torkſey Lock*, that is about 4½ inches higher than the framed bar, it will anſwer all theſe purpoſes. This would be eaſily conſtructed, extending 100 feet eaſtward from the eaſt end of the wharf wall, on the ſouth ſide of *Foſſdyke*; but as its diſcharge cannot be permitted to over-ride the *Fenton Drain*, the preſent ſouth bank of the *Foſſdyke* muſt be carried forward from the eaſt end of the weir, between the weir's water and the *Fenton Drain*, quite up to the walls of *Torkſey Bridge*; and to be made proof, ſo that the water ſhall never, after paſſing the weir, flow into the drain: and, furthermore, as the *Trent* floods frequently greatly over-ride the *Foſſdyke* waters, even in their higheſt condition, it will be neceſſary that the water of this weir ſhould be conveyed to *Trent* by a ſeparate paſſage, intermediate between the lock and *Fenton Drain*, whoſe out-let muſt be ſhut by doors pointed towards the *Trent*. A proper capacity for this paſſage will be about 8 feet wide, and 5 feet high in the clear; but its threſhold need not be laid ſo low as that of *Fenton Drain* by a foot, ſo that as the foundations may be compleatly in the dry, it will not be ſo expenſive as ſluice-work often turns out to be.

15th. The living waters of the *Till* can evidently have no other out-fall than into the *Foſſdyke*. The *Foſſdyke* will be, by the propoſed mode of ſupplying it with water from the *Witham*, held about 10 inches higher in very dry ſeaſons than it formerly was; but if the *Till*, which has now little or no banks, was imbanked 10 inches, it would at all times be as competent to hold in the living waters as now, before the adjacent meadows were overflowed. But let us ſuppoſe it imbanked 2 feet, yet as the ground is low on both ſides, but the loweſt in *Saxelby Meadow* near *Haddow Bridge*, which then would not be more than 2 inches above that advanced height of the ſurface of the *Foſſdyke*, this would neceſſarily be too ſmall an elevation of ſurface for theſe grounds ever to have a competent drainage; but as they are but of ſmall extent, when the living waters of the *Till* are ſo imbanked from them, a very ſmall tunnel, with a competent fall, would effectually drain them; for this purpoſe I would propoſe to drain them by means of a leaden pipe of 5 inches bore, under the *Foſſdyke*, into the drain propoſed to be carried on the ſouth ſide to *Saxelby Paſture*, laying alſo a ſmall common tunnel under the *Till* to communicate a few acres of drainage from *Haddow Meadows* (which are the higher) into *Saxelby*. I prefer, in this caſe, a leaden pipe, becauſe it may be lowered into the water, and compleated, without ever interfering with the navigation at all. Or, if better approved, theſe meadows near *Haddow Bridge* may drain by a communication acroſs the *Till* as aforeſaid, (but from *Saxelby* into *Haddow*) and then by way of *South Carlton* to the great iron tunnel propoſed in Article 8.

OPERATION of the preceding ſcheme.

UPON my late view I found the pen of *Lincoln Lock* to be good 14½ inches, with a competent fall for the current waters of the *Witham* through *Lincoln* and the *Slaker* drains, which I eſtimate at 1½ inch more, that is in the whole good 16 inches; it is therefore manifeſt, that by the means propoſed theſe 16 inches will be added to the natural fall of the drainage-waters that they now have into *Brayford Meer*; and the living waters of the *Witham* will then get diſcharged as they do now, and the internal drains being carried upon dead level bottoms, and dug below level till they get to the pinch of their reſpective ſervices, they will perform their drainage down to the dead level of their out-fall, in which caſe the point in *South Carlton*, that is reported to have had but 1 foot 2¼ inches elevation above *Brayford Head*, as it was in 1762, that is, but 8¼ above the level of *Brayford Meer*, as I found it the 31ſt of Auguſt laſt, will then have a fall of 2 feet ¼ inch from the ſaid ſurface to its out-fall; and the low ſlade in the weſt of *Skellingthorpe*, that was the ſame day 6 inches above *Foſſdyke*, (that is above *Brayford Meer*) will have a fall of 1 foot 10½ inches to its out-fall, which will fully ſuffice for a perfect drainage in ſeaſons moderately dry; but this being ſomewhat leſs than what has been eſteemed compleat, I muſt beg leave in this place to take notice, that formerly, when it was not the practice to dig drains below the dead level of the out-fall, nor to carry their bottoms upon a dead level, but riſing towards the country to be drained, it was then held neceſſary to have a calculation that the utmoſt reduction of the water within ſoil ſhould not be leſs than 2 feet. But the experience of the laſt 20 years has informed me, that where meaſures are taken to make the drains readily and ſpeedily, (after the top waters are diſcharged) reduce their water's ſurface *one foot* within ſoil where it is tolerably firm, will form a very effectual drainage, and in ſoils leſs firm 18 inches done ſpeedily will be full as effectual as an ultimate of 2 feet performed in that ſlow lingering manner which is the conſequence of ſhallow drains, containing no competent body of water in the bottom, to be moved; for let the body be however great, gravity acting with equal force on every particle, the fall being the ſame, will give every particle an equal velocity, and conſequently the whole. Now, as I found *Saxelby Meadow* was elevated above *Foſſdyke* 11 inches, it will, by what is propoſed, be elevated 2 feet 3 inches above its out-fall, and therefore ſeveral inches to ſpare to give its water a competent velocity through the pipe.

Hence it is evident, that the drainage of all the low grounds will be compleated in all ſummer ſeaſons, but will, as at preſent, be ſubject to be overflowed by the great winter's floods, but whoſe top waters will be more ſpeedily run off by the diſcharge

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into *Trent*, and by the drainage waters running off with a good current, when at prefent they do not run at all.

By avoiding all imbankments of the *Witham*, and the waters allowed to fpread as at prefent, all oppreffion of the drainage lands eaft of *Lincoln* is avoided; and in running off their ultimate drainage waters of the weft country more fpeedily, the eaft country will be greatly benefited, becaufe they will be fooner ridded of their weftern waters coming upon them; for this muft be laid down as a rule, that in like circumftances, the lands downward upon a ftream can never expect to drain prior to thofe above them, and therefore the fooner the waters of thofe above are difcharged, the fooner the drainage of the whole will be compleated.

The navigation eaft of *Lincoln High Bridge* will be greatly benefited, becaufe *Brayford Head* being cleared away down to the level of the floor of *Lincoln High Bridge*, will give 1 foot more water than at prefent, and the like advantage would take place quite through *Lincoln*, if the *Witham*, eaft of the faid bridge, was fuitably cleared.

The *Bofton* out-fall will alfo receive benefit, notwithftanding that fome of the top waters will be difcharged into the *Trent*, becaufe it can be no advantage to a country already oppreffed with water to receive an addition; and as the follow of the living waters will be continued in a more full body after the extreams are gone, the powers of fcouring will be continued to a period, when otherwife they would have ceafed.

In order to ftate the advantage to the *Foffdyke* navigation, and its relation to the drainage of the country, it will be neceffary to afcertain fome fixed points of level.

In the year 1762 it was afcertained by Mr. GRUNDY and myfelf, that when there was $4\frac{3}{4}$ inches depth of water over *Brayford Head*, the furface was then $5\frac{1}{4}$ below the top of the *Aifler* courfe of the *Lincoln* ftone in the face of Mr. *Ellifon*'s wharf, confequently the faid courfe was at that time 10 inches above the natural ftaunch of *Brayford Head*.

On reviewing the fame in the year 1782, I found 1 foot water upon *Brayford Head*, (as held up by the ftaunch of *Lincoln Lock* below) and at that time its furface was 4 inches below the faid *Aifler* courfe, confequently the *Aifler* courfe 16 inches above *Brayford Head*, as it now is; that is, *Brayford Head* in 1782 was lower by 6 inches than in the year 1762, and the furface of the water of *Brayford Meer* was $1\frac{1}{4}$ higher. I would therefore recommend that the crown of the propofed weir to pen the water in *Foffdyke*, and

over which the furplufage fhall fall into *Brayford Meer*, to be 5 inches higher than the faid *Aifler* courfe, which in fact will be all that will be gained to the *Foffdyke*; becaufe it is faid, and I fuppofe may be proved by evidence, that when this wharf was built about 40 years ago, the faid *Aifler* courfe was compleatly covered with water, that ftone being of the reputed quality not to bear the weather. The crown of this over-fall being about 11 inches lower than the propofed weir at *Torkfey*, will therefore be the gauge height of the *Foffdyke* navigation, whenever the flood waters do not raife the whole country above that level; and whenever that is the cafe, it will be proper to open the gates of the new propofed lock joining *Brayford Meer*, to let the flood waters of the *Till* have a free vend, fo as not to be unneceffarily accumulated upon thefe lands, that neceffarily drain into the *Foffdyke*.

I come now to prove laftly, that the whole of thofe lands, that neceffarily drain into *Foffdyke*, will be benefited by the alterations propofed; becaufe, as thofe all lay weftward of *Saxelby*, the difcharge by the weir at *Torkfey* will have the greateft and quickeft effect upon them in running off their top waters the moft fpeedily; and refpecting their ultimate drainage, it is manifeft, that whenever the waters of the whole country is above the propofed gauge height of *Foffdyke*, that it will be the fame thing to them, whether the over-fall at *Brayford* is in being or not; if, therefore, when at or under that height, all thefe lands have all the ultimate drainage they have now, or can have, they can be no lofers in that article.

The only drain into *Foffdyke*, that has the appearance of being in the leaft likely to be affected by the propofed advancement of the furface of the *Foffdyke*, is *Thorney Drain*; I mean that with a pair of doors at *Drinfey Nook*. Of the circumftances of this drain I took particular notice, and muft infer, that in point of ultimate drainage it fully does its bufinefs; becaufe if it did not, as I found the water of *Foffdyke* juft covering the threfhold, and a rife of the pavement or floor, from the threfhold of the door towards the land, of between 9 and 10 inches, I conclude, if this drain did not, in its prefent circumftances, do its duty, this rife in the pavement, which operates as a dam, being taken away, and the bottom of the drain lowered correfpondent thereto, it would be enabled to have run off the water lower by all this difference. I took a very careful level between the furface of the water of *Foffdyke* as it then was, and the top of this ftone pavement, and found that the rife was 9¼ inches in the compafs of 3 yards. The water being then 4 inches below the *Aifler* courfe at Mr. *Ellifon*'s wharf, if raifed 5 inches above it, this would make 9 inches; that is, the furface of *Foffdyke* would be ftill a quarter of an inch below the paving, and if *even* with the top would

be

be no impediment to any water flowing over it, for water could not flow over it without having ſome thickneſs, or depth upon it; and if it was 2 inches deep, it would have an immediate fall of 2 inches into *Foſſdyke*, by which it would be delivered as fully, freely, and uninterruptedly, as if it had a pit to fall into from the top of the pavement, of 100 yards deep; and in fact, as the drain's bottom (which I purſued about half a mile) ſeemed to lay nearly on a level with the top of the paved floor above mentioned, and was greatly trod and poached by the feet of cattle that made their paſſage along it, to eat the graſs upon its ſides, the condition of it is ſuch, that if the *Foſſdyke*, inſtead of being raiſed 9 inches above the level it then had, was raiſed 15 inches, I would engage, if neceſſary, to make it run off its water lower at half a mile diſtance after that, by digging it as deep as the threſhold of the ſluice, than it can do at its preſent depth and condition, though the *Foſſdyke* was totally emptied of water. It will therefore clearly appear, that the difference of an inch or two that may occaſionally be made by the thickneſs of the ſheet of water going over the over-fall at *Brayford* (or even if it was 6) will make no ſenſible difference in the effect of the operation of this drain, to which the more quick running off the top waters being the only thing deſirable.

Auſthorpe, December 31, 1782. J. SMEATON.

PROBABLE ESTIMATES of the expence of the above works.

1ſt. For ſuch works of drainage as would be neceſſary in caſe the *Foſſdyke* navigation was to remain in its preſent ſtate.

	£.	s.	d.
To removing *Lincoln Lock* and *Staunch* above *Sincil Dyke*, deepening the channel where neceſſary up to the ſame, and making good the wharfs, ſay	200	0	0
To ſcouring out and deepening *Sincil Dyke* from its tail to the tail of the *Great Gowt Drain*, and from thence the *Great Gowt Drain* to the *Witham*,	172	0	0
The contingence of under-pinning the two bridges upon the *Great Gowt*,	20	0	0
To making the ſubterraneous tunnel under the *Witham*,	150	0	0
To ſcouring out the *Leſſer Gowt Drain*, and remainder of the *Sincil Dyke* to the *Witham*,	33	0	0
To weirs at the head of each,	30	0	0
To the drain leading from the ſubterraneous tunnel to the point of departure of the two drains, according to Article 7th, being 400 roods, at 9*s*. 6*d*.	190	0	0
To three lengths of iron pipes, 3 feet diameter, for the grand ſubterraneous tunnel croſſing *Foſſdyke*, weight 5 tons 15 cwt. at 16*l*.	92	0	0
To bolts, jointing and laying,	10	0	0
To brickwork at the two ends,	20	0	0
To taking off the water and pumping,	25	0	0
Carried over £.	942	0	0

	£.	s.	d.
Brought over	942	0	0
To continuing the drain from the ſaid point of departure in *Skellingthorpe*, through the iron tunnel to *Biſhop's Bridge*, being 332 rods, at 8*s*. - - - -	133	0	0
To rebuilding *Biſhop's Bridge*, - - - - -	10	0	0
To continuing the drain from the ſaid point into *Skellingthorpe*, upon a 9 feet bottom, to the point K, being 410 rods, at 8*s*. - - - - -	164	0	0
To continuing the ſaid drain from the point K to the weſt boundary of *Skellingthorpe*, 333 rods, at 6*s*. - - - - - - - - -	100	0	0
£.	1349	0	0
To 10 per cent. contingencies upon the above articles, - -	135	0	0
£.	1484	0	0

N. B. As I ſuppoſe the truſtees of the *Boſton* navigation muſt be conſidered as aggreſſors, the removal of the lock and ſtaunch ſhould be at their expence.

ESTIMATE of ſuch works as will be neceſſary for the improvement of the *Foſſdyke* navigation upon the plan propoſed.

	£.	s.	d.			
To building a new lock between *Foſſdyke* and *Brayford Meer*, digging and pumping - - - - - -	500	0	0			
To additional work at the *Witham* tunnel, to make it ſerve as an aqueduct bridge over the drain, and to receive a gate for regulating the water,	120	0	0			
To cutting the aqueduct from the ſaid tunnel to the *Foſſdyke*, for carrying the water for navigation, being 240 rods, and ſecurely banking the ſame, at 12*s*. - - - - - - -	144	0	0			
To two communication bridges over the ſame, if of brick, 20*l*. each, -	40	0	0			
To making an over-fall from *Foſſdyke* into *Brayford Meer* of brick or ſtone,	100	0	0			
To making a ſtaunch at *Brayford Head*, - - - -	150	0	0			
To deepening and ſcouring from *Brayford Meer* to *Lincoln High Bridge*,	25	0	0			
				1079	0	0

The following works I look upon as contingent upon the riſe of the water in *Foſſdyke*.

To carrying forward a drain for the weſt bounder of *Skellingthorpe* through the corner of *Saxelby Paſture*, and by a leaden pipe acroſs into *Saxelby* and *Haddow Meadows*, length 256 rods, at 5*s*. - - - -	64	0	0
The leaden pipe 12 cwt. at 1*l*. 1*s*. - - - - -	13	0	0
Carried over £.	77	0	0

	£.	s.	d.			
Brought over	77	0	0			
To folder, labour, laying, and fixing, - - - - -	5	0	0			
To brickwork at each end, with proper grates to ſhut and hinder it from choaking and running at improper times, - - -	10	0	0			
To banking upon the *Till* up to its diviſion, length 88 rods on each ſide, at 2 *s*. 6 *d*. per rod, - - - - -	22	0	0			
To a tunnel acroſs the *Till*, wood and laying, - - -	2	0	0			
				116	0	0
				£. 1195	0	0
To 10 per cent. contingencies upon the above articles,				120	0	0
				£. 1315	0	0

The making the weir at *Torkſey*, being advantageous not only to all the lands in queſtion, but to the navigation, by more readily freeing the ſame from extreams of water, and alſo by quieting the apprehenſions that the land-owners might entertain from the riſe of the ſurface of *Foſſdyke* in dry ſeaſons, it ſeems to me ſhould be done at a joint expence.

To making the weir, walling, paving, and ſecuring the channel for carrying off the water, imbanking between the ſaid channel and *Fenton Drain*, making the tunnel through the road, and pointing doors towards the *Trent*, cannot lay at leſs than - -	500	0	0
Contingencies upon it at 10 per cent. - - - -	50	0	0
	£. 550	0	0

ABSTRACT.

	£.	s.	d.
General drainage ſcheme, - -	1484	0	0
Foſſdyke navigation, - -	1315	0	0
Torkſey Weir and accompanyments, -	550	0	0
Total	£. 3349	0	0

Auſthorpe, December 31, 1782. J. SMEATON.

HOLDERNESS LEVELS.

REPORT of JOHN SMEATON, annexed to a Report and Estimate of Mr. GRUNDY's, concerning the Drainage of *Holderness Levels*.

HAVING carefully perused the foregoing observations, and also compared them with my own taken upon the place in the month of November last, and finding no difference between them that can any ways affect the practicability of the proposed drainage, or the general scheme to be made use of for that purpose; and having also considered the causes assigned by Mr. GRUNDY for the drowning of this level, and the expedients to be made use for the remedy of the same, I entirely concur with him in every essential point. But as a number of adverse accidents have prevented us from meeting upon this business, according to the desire of the proprietors, which has prevented our comparing our ideas together; and as mens ideas often vary in particulars though they agree in general and material points; and as I find that some things have struck me in somewhat a different light to what they have done Mr. GRUNDY, I think it my duty to point out the same, not so much by way of correction of what he has proposed, as by way of supplement.

1st. In regard to the out-fall clough, *Marfleet* must strike every one, at first sight, as being the most eligible place; and, was there any want of fall, would certainly be so; but as there appears an ample sufficiency of fall into the river *Hull* at the *Sugar-House* clough, it's being so much above low water in the river *Humber*, allows it to run so much the longer; and if laid nearer low water mark (without which it could have no preference upon the *Humber*) it would be more difficult to maintain a channel from the clough to low water mark; and the shore being flat and muddy, and the water ebbing out a great way, the sea-doors would be more liable to be silted up in dry seasons. I can therefore hardly tell how to give the preference to *Marfleet*.

2dly. Was the eastern main drain, instead of going round by *Gold Dyke Stock*, to be conducted from *Old Williams* at *b*, through *Fordyke*, to about the midway between *Fordyke Bridge* and *Fossam Style*; and there making an obtuse angle, to meet the eastern drain, about the point *VI.* and then to proceed together in a right line to *D*, the course of the main drain would be shortened near upon a mile, which, according to the laws of drainage, is eligible, in case other circumstances of greater weight do not counteract; and then the course of the drainage of *Sutton Carr*, &c, which would be north, would be more natural; for, according to my information, those carrs are deeper about the fillings,

fillings, and *Chester Hole*, than near *Gold Dyke Stock*. The lands on the south of *Gold Dyke Stock* could drain as at present.

3dly. In case any objection is raised by the proprietor of *Wagben*, now under drainage by engines (which if this scheme takes place will be unnecessary) the eastern drain may be brought from the angle between *K* and *L*, in *Weel Carr*, through the main drain, under *Mieux Bridge*; and turning S. E. near *Lamber Coat Bridge*, to fall into the eastern drain, in a proper direction, between *b* and *c*; and though this course would be near two miles longer than the eastern one already marked out, and therefore less eligible, yet as there is fall enough, I propose it as a practicable scheme in case of difficulties.

4thly. I apprehend a sluice of less dimensions than 24 feet water-way, would drain these levels, when the banks against the river *Hull* are made tight and firm; as it seems to me that country clew would be almost sufficient, was it placed where there was a proper fall: however, I would advise nothing less than two tuns of 18 or 20 feet, but dimensions, in this case, if an error, is one on the right side.

5thly. The places of the present cloughs are very proper for tunnels for taking in water from the river in dry seasons; but, as I cannot suppose, after the above works are executed, that they will ever run, I cannot think them worth maintaining in their present form. The present extraordinary inundation, I suppose, to be principally owing to the badness of the banks against the river *Hull*, which allow a considerable part of it's contents to be discharged upon this level.

6thly. In regard to the estimates, the shortness of the time that accidents have allowed me for these remarks, puts it out of my power to enter into them particularly; but well knowing Mr. GRUNDY's correctness and assiduity in those matters, I have only to observe, that, though I think he has allowed a sufficiency of dimensions, I should be glad he would reconsider whether the price allowed for the spade-work will be sufficient also. On this account, I would count the sum of £ 10652, exclusive of the articles of surveying, planning, schemes, estimates, supervising and other contingencies, and procuring the act.

Austhorpe, 12th January, 1764. J. SMEATON.

EXAMINATION of Mr. GRUNDY's plan for a fea fluice for the drainage of *Holderneſs Levels*, by JOHN SMEATON.

THE general deſign and idea of this fluice I much approve; but as I think it may be made ſtronger with the ſame expence, I therefore ſubmit the following remarks to Mr. GRUNDY's conſideration.

1ſt. The fluice pit is directed to be dug 3 feet below low water mark, and the floor to be laid 1 foot below ditto.

	Ft.	In.
Thickneſs of the mud ſells - - - - - - - -	1	0
The ground ſells being let down thereon, I ſuppoſe 2 inches, will riſe	0	10
Thickneſs of the plank - - - - - - - -	0	3
The pointings being let into the floor, I ſuppoſe 1 inch, riſes - -	1	1
Total riſe above mud ſells pile heads, - - - - - -	3	2

Quere, Does Mr. GRUNDY propoſe letting the mud ſells into the bottom 14 inches? if ſo, it ſhould be more clearly expreſſed; as I ſuppoſe it is the ſecond floor, or top of the threſhold, that is to be 1 foot under low water.

2dly. It is propoſed to pile the mud ſells at every 6 feet, ſo that every other ground ſell will bear hollow upon the mud ſell, which I ſuppoſe is intended for it's principal bearing; and every ground ſell, being piled in the intermediate ſpaces, will have a ſuperior bearing to that where the walls ſtand; I would, therefore, propoſe to pile the mud ſells under the interſection of every ground ſell, and omit the intermediate piles, or do them only with ſlabs ſpiked againſt the ground ſells, after laid; but this, in my opinion, is unneceſſary; but I would add piles under every ground ſell anſwerable to the faces of the pier, for the length of the part that at preſent bears hollow, and on one row of piles, at 6 feet diſtances only; this middle row under the pier, for the arches length, I would ſtill continue at 6 feet diſtances. In this way, mud ſells of 12 × 6 will do as well as 12 × 12, and the timber ſaved may, if thought neceſſary, be employed in ſlab piling the intermediate ſpaces.

3dly. The projection of the floor beyond the walls, I think not only an uſeleſs expence, but prejudicial in effect, becauſe the back ſide of the wall bears hollow, and not immediately upon the pile heads; 'tis true, a wall of this ſort is not inclined to fall

fall backwards, but if the ground ſhould prove bad, and the wall be inclined to ſettle, (for which cauſe only piles ſeem neceſſary behind the front) they had better be applied directly underneath; and if the two outſide mud ſells, anſwerable to the back of the walls, are piled at 6 feet diſtances only, I think it ſufficient.

4thly. The row of dovetailed piles under the points of the projection of the pier, I think may be ſafely omitted, unleſs the ground is very bad indeed.

5thly. If 9 inch ſpikes are intended for the 5 inch plank piling, they will reach only 4 inches into the wood; I have, therefore, ſuppoſed them, in the eſtimate, to be of 11 inches.

6thly. Out of the timber ſuppoſed to be ſaved as above, I would lay an additional ground ſell cloſe to the other, directly under the points of the pointings, that the jagged bolts may there have ſomething elſe beſides the plank to hang by; but to diſcontinue them upon the mud ſells in the face of the walls: the three ground ſells and plank piles to be all bolted together. This laſt ground ſell I would ſupport by 4 piles, correſpondent to thoſe marked *dddd.*

7thly. I think 1 foot riſe at the threſhold very ſufficient, and the ſecond floor plank may be of two inches, or the ſecond beams of 12 × 9. The 20 inch bolts propoſed for the 14 inch pointings, leaves but 6 inches to go into the wood below, of which 2 inches is plank; they ſhould be two feet at leaſt.

8thly. It would conſiderably ſtrengthen the pointings to put a brace or ſtretcher of an equal height with themſelves, croſs the pier, according to the direction of the dovetail piles; ſo that the ſtring pieces, theſe braces, and the head of the threſhold, would all mitre together; and in like manner to fix on a piece jump againſt the outſide heels, to reach about 6 feet into the wall, and to be bolted on with two jagged bolts, each the ſame as the pointings are fixed by, for which there is proviſion in the eſtimate.

9thly. If the lime rubble is mixed with a little quick lime it will ſwell and become quite compact, which method I have uſed in fillings; and the ſecond floor I think had better be filled with ſolid brickwork.

10thly. The projecting pier I think had better be no longer than ſufficient to faſten the ſtuds, as the water will thereby more readily act behind, and ſhut the doors.

11th. In regard to the plan of the walls, I think a 5 feet baſe, the length of the arches in this light, unneceſſary; that as the arches will ever prevent the external preſſure of the earth from driving them inwards, a wall of 4 feet baſe and 3 feet at the ſpringers will be ſufficient; but conſidered as an abutment to the arches, independent of the weight of earth to be rammed behind, I think it inſufficient for a height of 12 feet; in this light the baſe had better be 7 feet, and 3 feet at top; the contre forts will undoubtedly ſupport the extremities of the arches, but a 15 feet hollow bearing, where there is any dependence, I think is too great in brickwork or maſonry.

12th. A baſe of $4\frac{1}{2}$ feet for the wing walls, is certainly too little for a wall that is to riſe at a mean 22 feet, without the help of land ties, or croſs beams; and, as I am very averſe to thoſe expedients, I would propoſe to make the baſe of the wings, at the ſet-on to the body, 9 feet thick; 6 feet thick joining the returns, and 6 feet for the returns; and to make regular ſets-off on the back ſide, ſo as to be every where 2 feet at top; this will reduce the walls to full as ſmall a ſize as is ſuppoſed at the height of 12 feet; ſo that the only addition will be 1 foot 6 inches mean thickneſs upon 12 feet high in the wings, and 1 foot thickneſs to ditto height in the returns, which, with the contre forts in the wings and returns, will make about $7\frac{1}{2}$ rods of brickwork; which at 6 *l.* per rod comes to 45 *l.* to do it durable and laſting, whereas with land ties and beams it comes to 57 *l.* 8 *s.* No addition of expence in the floor will be required, or alteration, ſave that I would conform it to this figure; and it will be neceſſary to lay in, inſtead of common planking, ribbands or whole pieces of 6 inches thick, in the face of the wing walls, to hinder their ſliding upon the floor.

13th. As the upper pointing is difficult to be ſupported, from the preſſure of the water downwards, I have propoſed in the eſtimate to ſuſpend them, by iron loops and ſtays, to the key-ſtones of the arches, and plank them flat upon the top.

14th. I apprehend Mr. GRUNDY has, in the height of his doors, had a view to the paſſages being navigable; otherwiſe I think, if the doors were only 8 or 9 feet high, (which would be fully ſufficient for the diſcharge of the waters) they would be lighter, and therefore move more readily as well as be in effect ſtronger.

Auſthorpe, 13th December, 1764. J. SMEATON.

P. S. It ſeems to me that there is not occaſion to dig the ſluice pit to ſo great a general width as 65 feet: was I to execute it I ſhould not open the ground to take in more than the extremity of the walls at bottom, and notch in the abutments, returns,

&c.

&c. in which case the main pit will not be above 50 feet bottom. I have also altered the position of the sluice pit in the general plan, in order to give it a better direction into the river, which, being in dotted lines, will readily be distinguished.

N. B. I have in the estimate supposed the walls to be carried up 12 feet high, the same thickness as ordered for the base.

ESTIMATE of Mr. GRUNDY's plan for a sea sluice for the drainage of *Holderness Levels*.

CARPENTRY.

		Cube Ft.
In 84 piles under the mud sells, being 10 inches by 12 head, and 10 feet long, 1 piece of 12 inches square and 10 feet long, make 2 piles; therefore the solid contents, - - -		420
In 7 mud sells, 64 feet long, 12 by 12, - - - - - -		448
In 96 bearing piles, 10 by 12 head, and 10 feet long, - - - -		480
	Cube Ft.	
1 Grounding to sea sheet piling, 73 feet long, 12 × 12, - - -	73	
9 Ditto in the sea apron, mean length 49 feet, 12 × 12, - - - -	441	
2 Ditto under the sea doors, 62 feet long, - - - - - - -	124	
5 Ditto under the body of the sluice, 44 feet long, - - - -	220	
2 Ditto under the land doors, 57 feet long, - - - - - -	114	
4 Ditto under the land apron, 45 feet long, - - - -	180	
1 Ditto to land sheet piling, 62 feet long, - - - - - -	62	
In 24 ground ways, 12 × 12, - - - - - -		1214
In 2 rows of 12 feet dovetail piles under extremity of the sea aprons and sea doors, length 134 feet, there is feet superficial, - - - - - -	1608	
In 2 rows of 10 feet ditto, length 106 feet, feet superficial, - - -	1060	
Superficial feet of dovetail piles, - - - - - - - -	2668	
Allow ⅛ for tongueing - - - - - - - -	334	
Superficial feet, 5 inches thick, - - - - -	3002	
The solid contents thereof is, - - - - cubic feet,	1251	
1 Row of ditto in the extremity of the land apron, 4 inches thick, and being in length 62 feet, and allowing ⅛ for tongueing, make, in solid contents, - - -	207	
Timber in the 5 rows of dovetail piling, - - - - - - -		1458
3640 Feet superficial of plank in the floor, being 3 inches thick, contains solid, -		910

6 Ground

	Cube Ft.	
6 Ground sells for the second floors under the arches, mean length 21 feet, 12 × 10, solid contents, - - - - - - - - -	106	
4 String pieces, 20 feet long, 10 × 6 - - - - - -	36	
4 Pointings, 14 × 16, and 7 feet long each, - - - - - -	4[illegible]	
2 Land thresholds, 14 × 16, and $15\frac{1}{2}$ feet long, - - - -	49	
Plank for the second floor, 3 inches thick, 504 feet superficial, containing solid - -	126	
Timber in the second floor and thresholds, - - - - -		361
Riga timber in the floor, - - - - - - - -	Cube feet	5291

	£.	s.	d.
To *Riga* timber in the floor, 5291 feet solid, at 14*d.* - - - -	308	12	10
Allow for waste in converting to the proper scantlings one eighth - - -	38	11	7
To timber in the floor, - - - - - - - - -	347	4	5
To preparing and driving 180 piles of 10 feet long, at 2*s.* 6*d.* each pile, - -	22	0	0
To framing, sawing and laying the floor, containing 37 square, at 15*s.* - -	27	15	0
To 2668 feet superficial of dovetail piling, sawing, making and driving, at 4*d.* -	44	9	4
To laying 37 square of planking in the floor, including sawing and caulking, at 7*s.* 6*d.*	13	17	6
To framing and laying the second floor, containing $5\frac{1}{2}$ square, at 1*l.* 2*s.* 6*d.* -	6	3	9
Workmanship in the floor, - - - - - - -	114	5	7
Timber in ditto, - - - - - - - -	347	4	5
Carpentry in the floor, - - - - - - -	£. 461	10	0

Masons and Bricklayers work.

	£.	s.	d.
The external circumference of the walls and pier is 292 feet by 12 feet high, produces 3504 feet of face work, which will be, at a medium, 1 foot 3 inches thick of stone; this produces 4380 cube feet, which, delivered at 1*s.* 6*d.* per foot, comes to, -	328	10	0
The setting and making mortar for ditto, at 1*d.* per foot, - - -	18	5	0
This being supposed to be set 6 inches breadth in tarras mortar, and the hollow posts wholly bedded therein, will take 50 bushels of tarras, at 3*s* 6*d.* - -	8	15	0
To extra labour in beating the mortar made therewith, at 1*s.* 6*d.* per bushel, - -	3	15	0
To lime and sand for making the tarras mortar, and bedding the stone work, containing 14 rods, at 9*s.* - - - - - - -	6	6	0
Masonry to 12 feet high, - - - - - - - -	[illegible]	[illegible]	[illegible]
[illegible] to	[illegible]		

To

	Sup. Ft.	Solid Ft.
To stone facings for the wings and returns to 6 feet above the spring of the arches, - - - -	966	1208
To ditto in the 2 face walls, - - - -	1088	1360
To ditto in the 4 rampart walls, - - -	460	565
	2514	3133

	£.	s.	d.
To 3133 cube feet of stone work, at 1 s. 8 d. per foot, - - -	234	19	6
To setting ditto and making mortar, at 1 d. per foot, - - - -	13	1	1
To lime and sand for mortar for ditto, 10 rods, at 9 s. per rod, - -	4	10	0
Masonry above 12 feet high, - - - - - -	252	10	7
Masonry below 12 feet high, - - - - - -	365	11	0
Masonry in the face of the walls, - - - - - -	£. 618	1	7

Estimation of a rod of Brickwork.

	£.	s.	d.
To 4500 bricks, at 15 s. per thousand, - - - - -	3	7	6
To 20 bushels of *Houghton* lime, at 8 d. - - - - -	0	13	4
To 40 bushels of clean sand, at 3 d. - - - - - -	0	10	0
To workmanship, - - - - - - -	1	8	0
Rod of brickwork, - - - - - - -	5	18	10
This, in the following estimate, I call - - - - -	6	0	0

		£.	s.	d.
The whole contents in solid, to 12 feet high, is 13548 cube feet, from which deducting 4380, the cube measure of the masonry, there remains 9168 cube feet of brickwork, making 29,7 rods, at 6 *l.* - - - - - -		178	14	0
The brick backing for the wings, and returns, to make the whole 3 feet thick at a medium, - - - - - -	1690 cube feet.			
To ditto for the faces to make the same thickness, - -	1428			
To ditto in the rampart walls, to make the whole, at a medium, 2 feet 3 inches thick, - - - - - -	420			
To cube measure in the arches a brick and half - - -	712			
Brickwork compleated, - - - - - -	4250 cube feet.			
The upper works in brick contain 4250 cube feet, which, at 309 feet to the rod of 14 inches thick, contains 13,8 rods, at 6 *l.* - - - - -		82	16	0
Brickwork in the backing and arches, - - - - -		£. 261	10	0

Carpentry in the sea and land doors and pointings.

A sea door,	Ft. in cube.		£.	s.	d.
In 1 turning post, 13 feet long, 9 × 9,	7	4			
1 Clapping post, 12 feet long, 9 × 9,	6	3			
The under rail and upper ditto, 9 × 9,	7	11			
4 Rails, 28 feet long, 9 × 7 $\frac{1}{2}$,	13	3			
66 Feet of inch and $\frac{1}{2}$ plank	8	3			
Solid timber in each door,	43	0			
To 43 feet of timber in each door, framing and hanging, at 3*s.* 6*d.* per foot, is 7*l.* 10*s.* 6*d.* each door, and for 4 sea doors,			30	2	0
	Cube Ft.				
In the main beam for the pointings, 34 feet long, 12 × 14,	40				
The 4 pointings, 28 feet long, 12 × 12,	28				
The king pieces, 6 feet long, 12 × 12,	6				
The covering with 3 inch plank 36 feet superficial,	9				
To timber and framing in the pointings, at 3*s.* 6*d.*	83		14	10	6
Land doors, being 11 $\frac{1}{2}$ feet wide by 8 feet high, contain 92 feet superficial, and being 4 inches thick,	31				
With 4 battens on each side, 2 inches thick, 1 foot broad, and 8 feet long, contain 64 feet superficial,	11				
Solid timber in each land door, Feet	42				
To 42 cube feet of timber in each land door, framing and putting in place, at 3*s.* 6*d.* is 7*l.* 7*s.* each, and for 2 doors,			14	14	0
Carpentry in the doors and pointings,			£. 59		

Carpentry in the beams and land tyes.

	Cube Ft.	£.	s.	d.
To 4 land tyes in each sea wing, and 2 in each return, sea and land in all 16, to be 24 feet long, 10 × 6,	171			
To 16 cross pieces and ditto string pieces, 3 feet long, 10 × 6,	43			
To cube feet in land tyes, at 3*s.*	214	32	2	0
To 32 10 feet piles, 10 × 8 head; timber, making and driving, at 6*s.* each,		9	12	0
To 3 beams of *Riga* fir over the sea, and 1 over the land apron, mean length 33 feet, 12 × 12; 132 feet, at 14*d.*		7	14	0
To 16 knee pieces for the same, at 5*s.*		4	0	0
To making, getting into place, and fixing the beams,		4	0	0
Carpentry in the beams and land tyes,		57	8	0
Ditto in the doors and pointings,		59	6	6
Carpentry in the upper works,		£. 116	14	6

Iron Work.

	Cwt.	lbs.	£.	s.	d.
Tail ſheeting 73 feet, 146 of 11 inch ſpikes, -		146			
Row in point of pier 47 feet, 94 of 10 inch ditto, -		73			
Ditto in extremity of land apron 63 feet, 126 of 9 inch ditto,		72			
To ſpikes for the ſheet piling at $3\frac{1}{2}d.$ - - - - -		291 lbs.	4	4	10
To 16 bolts for bolting the 2 ground ſells and ſheet piles, together in the 2 rows under the ſea and land doors, weighing $4\frac{3}{4}$ lbs. each, in all 76 lbs. at 6 *d.* - - -			1	18	0
To 2500 8 inch ſpikes for the floor, weight 10 Cwt. at 1 *l.* 10 *s.* per Cwt. - -			15	0	0
To 28 jagged bolts, 2 feet long and $1\frac{1}{4}$ inch thick, weight 10 lbs. containing 280 lbs. at 4 *d.*			4	13	4
To ſpikes for the ſecond floor, 1 Cwt. at 1 *l.* 10 *s.* - - - -			1	10	0
			27	6	$2\frac{1}{2}$
Contingencies thereon, - - - - - - - -			2	13	$9\frac{1}{2}$
Iron Work in the floor, - - - - - - -			£. 30	0	0
To 4 pair of ∟'s and 8 ditto of ⊢'s for each ſea door, and for the 4 doors 48 pair, weighing, with their rivets, 14 lb. per pair, in the whole 6 Cwt. at 2 *l.* 2 *s.* - -			12	12	0
To ½ crown nails for the planking of the gates ¼ Cwt. - - - - -			0	10	0
		lbs.			
To 4 9-inch hoops for the feet of turning poſts, weight 10 lbs. each,		40			
To 4 8-inch hoops for tops of ditto, 9 lbs. each, - -		36			
To 4 2-inch gudgeons for top of ditto, 20 lbs. each, -		80			
To 4 loops or ſtaples for fixing ditto, 28 lbs. each, - -		112			
To hoops, loops and gudgeons, for ſea gates, - -		268 at $4\frac{1}{2}d.$	5		
	Cwt.	lbs.			
To 4 bottom gudgeons and 4 pots of caſt iron,	1	0	1	0	0
To 4 ſcrew bolts, 18 inches long, ¼ thick, weight		16			
To 4 ditto of 4 feet long for ditto, weight 7 lbs. -		28			
To bolts for the upper pointings, at 6 *d.* per lb.		44	1	2	0
To 2 ſets of loops and ſtays for hooking the upper points of the key-ſtone of the arch, 50 lbs. each, at $4\frac{1}{2}d.$ - - - - - -			1	17	6
To ſpikes for the planking of the upper pointings, - - -			0	5	0
To rivet nails for the land doors, 100 in each door, ½ inch thick, at 3 *d.* each, -			2	10	0

For drawing the land doors.

	lbs.	£.	s.	d.
To 2 claſps and eyes with rivets, - - - -	64			
To 2 ſtuds with plates for faſtening to the wall, 12 lbs. each, - -	24			
To 2 chains 16 feet long, ¾ iron, - - - -	146			
To 2 ſtuds and 2 loops for fixing ditto, - - - - -	16			
Fixed iron work for drawing the land doors, at $4\frac{1}{2}d.$ - -	250	4	13	9
Carried over,		29	10	

	£.	s.	d.
Brought over,	29	10	9
To a common hand-ſcrew fitted up for drawing the gates, - - - -	5	0	0
To 50 cramps for the cappings, 2 lbs. each, 100lbs. at 4*d*. - - -	1	13	4
To 5 pigs of lead to faſten cramps and iron work, at 16*s*. each, - - -	4	0	0
	40	4	1
Contingencies, - - - - - - -	4	15	11
Iron work in the upper works, - - - - - -	45	0	0
Ditto in the floor, - - - - - - -	30	0	0
Iron work in the whole, - - - - - - -	£. 75	0	0
To 188 cube yards of lime-ſtone rubbiſh, mixed with 1 buſhel per yard of quick lime, well blended together, and rammed in between the timbers of the floor before it is planked, - - - - - - - -	28	4	0
To ½ a rod of brickwork between the timbers of the ſecond floor, cloſe laid in and filled with mortar, - - - - - - -	3	0	0
Filling in the floor, - - - - - - -	31	4	0

ABSTRACT.

	£.	s.	d.
Carpentry in the floor, - - - - - -	461	10	0
Maſonry in the face of the walls, - - - - - -	618	1	7
Brickwork in the backing and arches, - - - - -	261	10	0
Carpentry in the upper works, - - - - - -	116	14	6
Iron works in the whole, - - - - - -	75	0	0
Fillings in the floor, - - - - - - -	31	4	0
Drainage of the water, ſupervifal, and contingencies, - - -	200	0	0
	£. 1764	0	1

BRISTOL BRIDGE.

QUESTIONS propofed by Mr. STRATFORD, Engineer, concerning *Briftol Bridge;* anfwered by Mr. SMEATON.

Quere 1ft. FROM the ftate of the old pillars, and ftrata below the bed of the river, to the folid red fand rock, will it be prudent, or advifeable, to attempt the conftruction of a new fuperftructure on fuch old precarious foundations?

Having duly confidered the feveral matters ftated in the foregoing difcourfe *, as well as the feveral plans, elevations, and fections, I am of opinion as follows:

Anfwer 1ft. As all the old pillars appear to be ill built and damaged, and not fufficiently deep below the bed of the river, which will always render them fubject to further injuries from the action of the water, which appears here to be very confiderable, I fhould think this fufficient to their condemnation, if the circumftances of their being ill fized, ill fhaped, and ill placed, were not in the prefent cafe to be added.

Quere 2d. From the forementioned account of the frefhes, will not any attempt to bar up the bed of the river under the bridge be extremely injudicious, and a meafure that will greatly add to the prefent inconveniencies felt at the head of the back?

Anfwer. The bars mentioned to be thrown up, both above and below bridge, have undoubtedly been formed by the matter removed by the current from between the piers; which removal has been occafioned by the bulk of the pillars too much ftraightening the water-way, which, increafing the current there, has taken out the matter and increafed the depth, thereby nature having in fome meafure relieved herfelf, by getting in depth what fhe was debarred from in width; an attempt therefore to refill thofe cavities will either be attended with the fame confequences, and an increafe of the bars, or, if the new matter to be added, is fo heavy and compact as to refift the current, the current muft be proportionably encreafed thereby. I fhould therefore think this expedient in this place very unadvifeable.

* Meaning Mr. *Stratford's* defcription of the fituation, condition, &c. of the old pillars, and of the feveral ftrata under the bed of the river, &c.

Quere 3d. The poſition of the bridge being a matter of moment in bridge building, will not the changing the preſent poſition of the old bridge be a real improvement to the part of *Briſtol* at the head of the back, as it will facilitate the paſſage of all ſorts of veſſels through bridge; and may not a reaſonable expence to gain that advantage be money judiciouſly expended for the benefit of the city of *Briſtol?*

Anſwer. All bridges ought as near as poſſible to have their piers parallel to the natural current of the water, in the place where they ſtand; yet a ſmall deviation therefrom, ſo far as it reſpects the paſſage of the water only, is not of great conſequence to a work that is otherwiſe firm and well founded: but in the preſent caſe, with reſpect to the laying and paſſage of veſſels, the deviation very unluckily happens to be the wrong way, and therefore in the reconſtructing this bridge ought to be rectified. I don't mean that the piers ought to be out of parallel with the ſtream, but if they had happened to have deviated as much the contrary way, there probably would have been no need of a change. This ought however to be attended to, that at the ſame time the freſhes, floods, and ſtrong ebbs, render the veſſels along ſide the quay leſs ſteady, it may be the means of preſerving the face of the quays from an addition of ſilt or mud; yet the quantity of alteration propoſed, cannot I think be attended with any danger from this quarter.

" Queſtion 4th. In caſe of a three-arched bridge, ſituated on ſo rapid a river as at *Briſtol*
" *Bridge*, will it not be more eligible to conſtruct the ſalient angles or becs of the piers
" with cylindric ſurfaces of 60 degrees, rather than an angle of 90 degrees, or
" rectangular?"

Anſwer. As the ſhoulder angles of the piers obſtructed the water's paſſage, and the more ſo as theſe angles are leſs obtuſe, in all currents they ought to be rounded off; provided this is done, it is little material what angle is formed at the bec; but no way is more advantageous than cylindric ſurfaces of 60 degrees, which is at preſent the practice of moſt foreign engineers.

" Queſtion 5th. The firſt deſign a ſingle arched bridge, the cord at low water mark
" 150 feet, the plumb or perpendicular $32\frac{1}{2}$ feet, the ſpringers of the arch to be carried
" down, and ſunk into the ſolid red ſand rock, according to the plan referred to;
" will there be any ſort of danger or hazard in executing a work of this large ſpan, under
" a ſuppoſition that the ſpringers of the arches are carried down to the ſolid rock?"

" N. B.

" N. B. The ſtone deſigned for the bridge is a ſand ſtone, which riſes ſoſt in the " quarry, but immediately hardens in the open air to an amazing firm texture, at the " ſame time the ſtone can be raiſed in blocks of any ſize: I propoſe one ſort of arch ſtones " of $6\frac{1}{2}$ feet long, and 3 feet in the ſuffit or thickneſs, and from 3 to 4 wide; the ſecond " ſet 4 feet 3 inches long; 4 or 5 feet wide, and of the former thickneſs; the counter " arch to bond in with the principal arch, according to the ſection referred to. The " ſtone deſigned for the counter arch is excellent, being 4, 5, or 6 inches thick, very " wide and long.

" The lime for the mortar of the bridge is of an admirable nature; one ſort will ſet " and cement under water, equal with Dutch terras; and the other will alſo ſet and " cement the ſtonework together, as if formed of one ſolid maſs.

" This arch from the ſpringers contains 125 degrees of a circle, conſequently is 5 de- " grees above $\frac{2}{3}$ of a ſemicircle, which PALLADIO recommends in all his bridges. " As this arch is to be founded upon the ſolid rock, this arch may be looked upon as " ſemicircular, as the rock may evidently be ſuppoſed the part of the arch deficient of a " ſemicircle. A great advantage in a ſcheme arch, built on a ſolid rock, is, that the " leſs number of degrees the arch contains, the ſtronger the arch will be."

Anſwer. I look upon it that no limit to the ſpan of arches, in proportion to their riſe, has as yet been found, ſince the wideſt and flatteſt arches that have been attempted, upon right principles, have ſucceeded as well as the narroweſt and higheſt, provided the abutments are good, and the ſtone and cement whereof they are compoſed are of a firm texture, as in the preſent caſe they are ſaid to be: and as no abutment can be better than a ſolid rock, and ſince the manner of carrying down the arch, and ſtepping it thereupon according to the ſection, is quite proper, I ſee no reaſon to doubt of ſucceſs, if built upon the plan now before me.

The *Aberthan* or *Watchet* lime, which I ſuppoſe is here hinted at, I look upon, from experience, to be the beſt in the world for works under water.

Queſtion 6th. The ſecond deſign I propoſe to conſiſt of a large central arch, and two ſide arches. In this deſign will it not be moſt adviſeable to carry down the piers and abutments to the ſolid rock.

Anſwer. Though I apprehend the piers of a bridge might be ſecurely fixed upon any of the ſtrata mentioned, by pileing and other timber-work, provided there was no other

other to come at, yet as a rock is undeniable, I look upon it worthy of a confiderable addition of expence to come at it in a work intended to be lafting: how far it may be practicable in the ftrata mentioned to get down to the rock by battardeaux, in the middle of the river, I am fomewhat dubious; and though it may be come at by the caiffoon method, yet, as I think to interpofe a grating or floor of timber between the folid rock and folid mafonry, is not quite the thing to be wifhed for; I fhould therefore prefer the fingle arch, as having fewer foundations, and thofe more eafy to be fenced off and come at, and fhould prefer the 150 feet arch to one of leffer fpan, as the abutments will advance lefs into the river.

Queftion 7th. The third defign, propofed by Mr. BRIDGES, where the new piers are to be feated on a coping on the old pillars. But as there are fo many real objections to this plan, will it not be the moft judicious and advifeable ftep entirely to reject every propofal already offered or to be offered for executing that vague fcheme.

Anfwer. As to Mr. BRIDGES's plan I can fay nothing, as not having feen it; but if the old piers are as reprefented, I think it quite wrong to make ufe of it at all, for the reafons in the firft anfwer. This I am fure of, if the bottom is unfound, no coping, or any thing elfe that can be done, can make them found. Befides, to leave the old fpreading bottoms to project under water much beyond the new fhafts, and that in an irregular manner, would be very prejudicial, not only to the paffage of the water, but the navigation; I therefore muft conclude, that if a new fuperftructure muft needs be built upon the old bottom, I think it moft advifeable to fhape the piers, and build the bridge conformable.

The queries anfwered by J. SMEATON.

Aufthorpe, November 24, 1762.

RYE

RYE HARBOUR.

The REPORT of JOHN SMEATON upon the harbour of *Rye*, in the county of *Suſſex*.

THE harbour of *Rye*, once ſo famous and flouriſhing, lays in the bottom of a bay, terminated by the point of *Dungeneſs* on the eaſt, and of *Beachy Head* on the weſt, but more immediately by *Point Fairlee*, which lays almoſt in the ſame line, at about the diſtance of 5 miles. This harbour, according to tradition, was formerly very large, capacious, and deep, ſo that many large ſhips might lay therein, ſheltered from all winds, at anchor at low water. In this ſtate the ſea waters every tide overflowed a very large tract of country (now converted into marſhes), the influx and reflux of which waters from and to the ſea produced ſo great a power of cleanſing and opening, as to maintain itſelf a channel wide and deep enough for the above beneficial purpoſes.

Now as the whole of the waters ſo flowing in and out each tide muſt paſs through the mouth of the harbour, the action thereabouts would be the ſtrongeſt of all, and in proportion weak towards the remote extremities: the mud, therefore, and impurities brought in by the ſea, and ſoil brought down by the rains from the high country, would firſt of all be lodged at thoſe extremities, which gathering by degrees, in proportion leſſen the capacity of the reſervoir, which of conſequence weakens the influx and efflux, and thereby increaſes the tendency to ſilt, or, as it is here called, to ſwerve up; and thoſe ſurfaces ſo overflowed being by degrees raiſed out of the reach of common neap tides, begin to gather a ſurface of graſs, which tempting the huſbandman to encloſe with banks, he thereby ſhuts out the ſea totally, and in conſequence weakens the cleanſing power more ſuddenly than would happen in a ſtate of nature; ſo that in time the whole of ſuch an inlet will be ſilted or ſwerved up, unleſs a ſufficient quantity of land or flood waters have their paſſage through the ſame to ſea; and the channel remaining at laſt will be in proportion to the quantity and rapidity of theſe flood waters. This is the natural tendency of every creek or harbour upon the ſea, but differing greatly in degree as ſituations and quantity of freſh waters from the land, and the impurity of the land or ſea water, differ in one place from another.

It appears further, that an immenſe quantity of flint, pebbles, or broken flints, rounded by the action of the ſea, commonly called ſtringle or beach, and which have either

either proceeded from the chalk cliffs on the coaſt, or have been waſhed up from the bottom of the ſea, are produced to the weſtward of this harbour, and being driven on the ſhore, which runs in a general direction nearly W. S. W. and E. N. E. the wind at any point between S. and S. W. cauſes the ſeas to ſtrike the ſhore in an oblique direction, and not only to heap up the beach upon the coaſt, but to drive it along the ſhore to E. N. E. into the bottom of the bay; that is, into the mouth of the harbour, from whence there is no poſſibility of return by a contrary action, becauſe all winds from E. to S. E. which ſhould produce that effect, are in a great meaſure land-locked, and not only ſo, but are generally leſs continued and violent than the South-Weſterly. Hence then it appears, that two powers of nature are together combined to produce the deſtruction of this harbour, viz. the ſilting within, and the action of the winds and ſeas without, upon the ſhingle, to block up its mouth; nor could this laſt be poſſibly avoided, in a very little time, was it not for the action of the land waters, which will always maintain themſelves a paſſage to ſea, (while they have no other) and though conſiderable in the winter ſeaſon, are yet very inadequate to the keeping open ſuch an arm of the ſea as this has formerly been, or even now is. The quantity of beach or ſhingle that has thus gathered at the bottom of this bay and mouth of the old harbour makes a ſurface of ſeveral hundred acres, the poſition of which in ſome meaſure appears by the plan hereto annexed, and is at preſent in an increaſing ſtate; for, as I am informed, that which at preſent is called the outermoſt weſt point has been formed within theſe ten years; and that which is now called the innermoſt was then called the outermoſt; and the point marked B in the plan was then called the innermoſt, which is conformable to a plan made in the year 1738. Hence it appears, that a ſucceſſion of points have formed themſelves to the weſtward of the harbour's mouth, every one leaving a more narrow paſſage than the former, the preſent opening between the preſent points not being above 100 yards wide. There alſo appears to be a body of beach, marked in the plan A, which is driving down from the weſtward, in all probability, and will form a point without the preſent, leaving a paſſage ſtill narrower. From this view it appears, that the old harbour has been ſubject to great mutation, and is likely to be ſubject to ſtill more, and all for the worſe; and all able artiſts, who have ſurveyed the ſame, have agreed, that nothing to purpoſe can be done towards reſtoring the old harbour, or maintaining the ſame in any tolerable ſtate. In this condition it appeared upon a ſurvey in 1698, by two Commiſſioners of the Navy and two Elder Brethren of the Trinity Houſe, by order of the Right Hon. the Lords of the Admiralty, who conclude their Report with ſaying, " And therefore we take this harbour to be almoſt entirely loſt, at leaſt in no condition to be preſerved for any purpoſe of the navigation." Indeed, three gentlemen, who were ſent to ſurvey the harbour of Rye, by order of the ſame board, in the year 1719, after declaring their ſenſibility

ſenſibility of the former utility of this harbour, and the bad condition it was then in, propoſe a remedy; but as this appears quite inadequate to the object, ſince that time a new harbour was projected, and in part executed, by the famous Captain PERRY, who, after performing ſeveral great works in *Ruſſia*, and effectually ſtopping the breach in the river *Thames* at *Dagenham*, was employed here; and this new harbour has been carried on, with ſome interruption, from that time to this. Its general deſign and ſituation is as follows:

The mouth of the new harbour is ſituated about two miles to the weſtward of the old one, where the coaſt makes nearly a ſtraight line for ſeveral miles together, and though altogether formed with beach, yet ſeems to have had no conſiderable increaſe of late years, at leaſt not ſince this harbour was begun; for though a ſucceſſion of ſhingle is moving to the eaſtward, it does not ſtay here, but lodges in the bottom of the bay. The coaſt being hereabout W. S. W. and E. N. E. as before mentioned, the mouth of the harbour points nearly ſquare thereto, that is, to S. S. E. or rather S. E. by S. At the foot of the beach, which is about low water mark at neap tides, begins a fine firm ſand, regularly inclined towards low water, which at ſpring tides is about 257 yards from the foot of the beach, and from thence inclines by very regular and gradual ſoundings, ſo as to make 20 feet water at low water ſpring tides, and about 23 feet at ditto neap tides, at above a mile right out from the harbour's mouth, which ſoundings gradually increaſe further out, and the whole of the bay is excellent anchoring ground, as I am informed. The tides here, at a common ſpring tide, riſe above low water mark 23 feet, and neap tides about 14, that is about 17 feet above low water mark ſpring tides, which are the greateſt tides I have met with on this coaſt. The direction of the tides is nearly along ſhore, and being ſome diſtance (on account of the depth of the bay) from the main channel tide, are very gentle, and are attended with this particular circumſtance, that whereas the main channel tide ſets to the eaſtward for ſome time (in moſt places three hours) after high water, which occaſions a ſtrong current to the eaſtward, at the time of high water; now in the bottom of this bay, the time of ſtill water, and that of high water, are both nearly the ſame, which is a great advantage to ſhips ſteering into the harbour's mouth, eſpecially in bad weather; all which circumſtances, viz. the great riſe of tides, the eaſineſs of the current, and ſtillneſs at high water, when veſſels chiefly go in and out, muſt be allowed to be advantages favourable to the conſtruction of an harbour in this place.

With reſpect to the harbour itſelf, in its original deſign, it had two ſtone pier heads projected into the ſea, as far as the foot of the beach, their diſtance 120 feet, which makes the opening of the harbour's mouth; but as the courſe of the beach was intercepted

cepted by the weſt head, and in conſequence a body of it collected behind the ſaid head, the weſt head has lately been advanced further out with timber and ſtone, ſo as to overlay the eaſt pier 210 feet, which addition is not only the means of preventing the beach from getting round the head ſo eaſily as before, but greatly facilitates the entry of the harbour, eſpecially in the time of heavy ſeas from the S. W. as I have had an opportunity of being eye-witneſs of a veſſel coming in for ſhelter under theſe circumſtances.

From the pier head the width of the harbour enlarges to about 200 feet wide, and is altogether in the form of a canal, which, in my opinion, is preferable to any other for an artificial harbour, on account of the advantages in ſcouring, where the whole depends thereon.

At the diſtance of 730 yards, or thereabouts, within the piers, is placed a large navigable ſtone ſluice, and the whole of the canal between the pier heads and the ſluice is formed into the arch of a circle of about 45 degrees; ſo that no part of the mouth of the harbour can be ſeen from the ſluice, nor any part of the ſluice from the mouth of the harbour; in conſequence whereof, not only the deſtruction of the ſluice-gates by the ſea's rolling in upon them, are prevented, but a ſpace of above 200 yards of the canal, from the ſluice downwards, becomes ſtill water, in time of the greateſt ſeas, at the harbour's mouth, which is particularly convenient for ſuch veſſels as come in for ſhelter, and only wait to take the advantage of better weather, or a favourable wind. At preſent the bottom of the channel between the pier heads is about 6 feet above low water mark at ſpring tides, and about 3 feet above the cill of the ſluice: ſo that at preſent there is 17 feet water between the heads at ſpring tides, and 11 feet at neap tides; but as the body of beach that ſerved as a dam in the harbour's mouth, to prevent the ſea from coming in till the works within were compleated, has never been totally removed, and as in its preſent ſtate a ſufficient body of back water cannot be collected for effectually cleanſing and keeping open the mouth of the harbour, it cannot be looked upon at preſent as having the greateſt depth of water of which it is capable. I am therefore of opinion, when theſe requiſites are provided for by compleating the whole ſcheme, that then the mouth of the harbour, as well as the internal part up to the ſluice, may be kept clear, at leaſt as low as the level of the cill of the gates; in which caſe the common ſpring tides will give 20 feet water into the harbour and through the ſluice, and neap tides 14 feet; which latter I apprehend to be ſufficient for common built merchants veſſels of 300 tons burthen.

The

The ſluice is built of *Portland* ſtone, and conſiſts of two openings, one of 40 feet, ſhut by folding gates pointed to landward, the other of 30 feet clear water-way, ſhut by five draw-gates of 6 feet wide each: the uſe of theſe gates is to ſhut in the tides received into the canal above the ſluice on tide of flood, into which veſſels may then paſs, or at high water through the great opening, or repaſs at high water or on tide of ebb; and gates being afterwards ſhut, and thereby a body of water penned into the canal above the ſluice, ſerves either to keep veſſels therein afloat during the whole time of tide, or being let off at low water by means of the draw-gates, produces a ſcour for keeping open the harbour below.

The length of the canal above the ſluice is half a mile very nearly, and at a medium is about 150 feet wide at the water's ſurface, 70 feet at bottom, and dug down to the level of the cill of the ſluice. This canal alone, excluſive of the outer harbour, will take in above 200 ſail of veſſels, but yet does not contain a ſufficient body of water to produce the neceſſary ſcours below; and furthermore, this part of the canal being liable to ſilt up by the depoſition of mud brought in by the ſea, will in a few years be choaked up, and rendered entirely uſeleſs; the ſilt being gathered at leaſt 4 feet deep at the head of the canal ſince July laſt, when the harbour was opened; what therefore is principally wanting to compleat what I apprehend to be the original ſcheme, is to bring the land waters and freſhes of three rivers, that now diſcharge themſelves into the old harbour of *Rye*, through the new harbour, by which means the whole will be kept clear, as appears to me for the following reaſons:

The river *Rother*, together with the *Breade* and *Tillingham* channels, which unite in the old harbour of *Rye*, are ſaid to receive the downfall and ſpring waters of above an hundred thouſand acres of land; the diſcharge from whence in rainy ſeaſons muſt be very conſiderable. But without entering into a minute diſquiſition concerning the quantity of ſurface, the moſt certain way of judging appears to me from obſervation of the ſize and ſort of channel that thoſe rivers reſpectively are enabled to maintain, ſo far up as where the ſilt, brought in by the ſea on one hand, and driven out by the land waters on the other, is already come to a balance; and ſuch I take to be the channel of the *Rother* immediately below *Scotch Flat Sluice*; the *Breade* or *Winchelſea* channel below *Winchelſea Sluice*; and the *Tillingham* channel about a mile above the *New Bridge* at *Rye*. Now it appears to me, that the *Rother* and *Tillingham* waters united are ſufficient to maintain a channel, from the new canal to the town of *Rye*, capable of carrying up veſſels of 300 tons; that the *Breade* channel is capable of maintaining a channel ſufficient for ſhips of 100 tons to *Winchelſea Sluice*; and that the three together are capable of preſerving an

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open channel through the present canal and new harbour, so as to make at least 14 feet water at neap tides, as abovementioned; and that the necessary widening these channels, for the purpose of discharge of land waters and navigation, will also furnish a sufficiency of reservoir for taking in the tide for the purpose of scours in dry seasons, when those rivers do not afford a sufficiency of water for that purpose; and as this part of the scheme is still to execute, I would recommend it to be done upon the following general principles:

1st, then, I am of opinion, that the present clear water-way at the sluice of 70 feet is sufficient for taking in as much tide-water as is necessary for the purpose of scouring the outward harbour, and for filling a channel sufficient for navigation to the towns of *Rye* and *Winchelsea*, and for bringing down and discharging the land waters.

2d. I am of opinion, that a greater capacity than is necessary for the purposes abovementioned is hurtful, as a channel too wide will be maintained from silting with greater difficulty; and the taking in too great a body of water will bring in a greater quantity of silt, and will occasion an unnecessary fall of water at the sluice, too great for the quiet passage of vessels; and that the tide falling without, before the internal parts are full to the same level, will occasion a diminution of depth of water for the vessels from the sluice upwards. I would therefore propose, that the channel of *Winchelsea*, from the upper end of the new canal to the town of *Rye*, be widened, deepened, and straightened, so as to be 50 feet wide in the bottom; each side to batter at the rate of 2 feet horizontal to 1 foot in depth; the bottom to be so disposed, as to make a part of a plane regularly inclined from the lower end of *Scotch Flat Sluice* upon the *Rother*, to the cill of the great sluice: in which case, as the low cill of *Scotch Flat* lays about $5\frac{1}{2}$ feet higher than the cill of the great sluice, the bottom of the new channel joining upon the new canal at C will be 7 inches higher, and the other end of the new channel D at *Rye* will be 2 feet 10 inches higher than the cill of the great sluice at the point D; the banks or walls of this canal to be set at least 40 feet from the brink thereof, and to be raised to 25 feet above the cill of the great sluice, to be 6 feet top, to batter 3 to 1 towards the canal, and 1 to 1 landwards.

3d. From the point D to make a cut to the north of the town of *Rye*, to fall into the river *Rother* at some convenient point, suppose E; this cut to be 40 feet bottom, to agree with the inclined plane aforesaid, its sides to have the same batters as the former, and its banks or walls to be raised to the same height, to have the same dimensions at top, the same batters and distance as before described, as far as the crossing of the turnpike-road F.

4th. To

4th. To fix a dam acroſs the river *Rother*, near below the point of diverſion E, and to erect a ſea wall from the ſaid dam, to ſome convenient point eaſtward, upon the preſent ſea wall of the marſh G, and to carry another ſea wall from the ſaid dam weſtward, to abut upon the turnpike road at F, which dam and walls are to be raiſed to an equal height with the adjoining wall againſt the marſh, to be 6 feet at top, and to batter both ways, as $2\frac{1}{2}$ to 1.

5th. As a bridge will be wanted upon the turnpike road, before mentioned at F, for croſſing the canal, I would propoſe it to conſiſt of 3 arches, one of 13 feet 6 inches wide, the others of 12 feet each; the large opening to be furniſhed with two pair of folding gates, pointed to ſeaward, and 1 pair of ditto pointed to landward; the cills of theſe gates to be laid even with the propoſed bottom of the canal at this place, that is, about 2 feet 10 inches above the cill of the great ſluice, and about 1 foot 8 inches below the lower cill, and 2 feet 11 inches below the cills of the navigable chamber of *Scotch Flat Sluice*.

6th. A navigable ſluice to be fixed acroſs the *Tillingham* channel, at ſome convenient place within half a mile above the bridge at the ferry, ſuppoſe at H, of 13 feet 6 inches in the clear, with a pair of gates pointing to ſeaward, and ditto to landward, with draw ſhuttles or ſlakers in the latter, and the walls or banks of the *Tillingham* channel, from the ſaid ſluice downwards, to its junction with the canal before deſcribed, to be heightened in ſuch manner, and in ſuch proportion, as is deſcribed for the main channel from the new canal to *Rye*.

7th. A dam to be fixed acroſs the preſent combined channel of *Winchelſea* and *Tillingham*, at or near the preſent new bridge at *Rye*, ſuppoſe at K, and the road to be carried over the ſaid dam; the top thereof to be made up to the ſame height as propoſed for the aforeſaid new channel from the canal to *Rye*.

8th. The channel of *Winchelſea*, from the new canal to *Winchelſea Sluice*, for the purpoſe of navigation, and alſo to obtain a ſufficient quantity of earth for the neceſſary ſtrengthening of its walls, to be widened and deepened at the head of the new canal, to 2 feet above the floor of the great ſluice, and to be carried upon an inclined plane, ſo as to agree with the cill of *Winchelſea Sluice* at that place; the batters of its ſides, the height, ſtrength and batters of its walls, to be the ſame as propoſed for the main channel from the new canal to *Rye*.

9th. That

9th. That in cafe the diverfion of the land waters fhall occafion the out-fall of *Wenway Sluice* to choak up, then a new channel to be cut, and fluices erected, for the difcharge of *Wenway*'s waters, above the propofed dam at E, into the *Rother*.

10th. That in cafe of the total choaking up of the old harbour's mouth, upon the diverfion of the rivers into the new harbour, as is to be expected, then the proprietors of fuch ground as is to be gained hereby, fhall have liberty to few the fame into the new channel, by an out-fall fluice or fluices, to be erected at their own expence, either in the new dam propofed in the 7th Article, to be fixed acrofs the old channel, near the new bridge at *Rye*, or to erect the faid fluice or fluices in any more convenient part of the banks of the new channel adjacent thereto.

11th. That in cafe it fhould hereafter appear, for reafons I am at prefent unacquainted with, to be more eligible to carry the *Rother* into the *Winchelfea* channel, on the fouth of the town of *Rye*; this appears alfo practicable on the fame principles; in which cafe, the fluice propofed at F, fhould be erected near the place of the propofed dam at K.

OPERATION of the foregoing conftructions.

AS the tide will be ftopped in the refpective channels by the fluices already erected, and propofed to be erected thereon, I find by computation that the whole cavity of the faid propofed channels would be filled through the prefent opening of the great fluice, in the time of a tide, to nearly the fame level within as without the great fluice, by a difference or fall no ways prejudicial to navigation through the fame.

That the faid cavity, containing near five times as much water as the prefent canal above the fluice, will be fufficient for the fcouring of the outward harbour in dry feafons, as the land frefhes in rainy feafons will be fufficient of themfelves according to all appearances. That the navigation for lighters, &c. up the *Breade* channel, will remain as it now is; and that the navigation of the *Tillingham* channel will be put upon a fimilar footing, that is, with an opportunity of penning in fo much water by the land doors as fhall be fufficient for navigation, confiftent with drainage; that the navigation up the *Rother* will not hereby

be

be interrupted, becauſe 'tis propoſed on tide of flood to take in as much water, above the propoſed ſluice at F, as will float the veſſels to *Scotch Flat Sluice*; but to ſhut out the top of the tides, which will in effect compleat the drainage of all the preſent extenſive ſalts included within the croſs walls, propoſed in Article 3.

That the drainage of the lands by the five waterlings, *White Kemp*, *Guildford*, and *Wenway Sluices*, will be upon a better footing than heretofore, becauſe having little pen upon them from without, the ſluices and banks will be ſubject to leſs repair, and will admit leſs ſea water in the drains by leakage, ſoakage, &c. and at low water will have a better diſcharge, becauſe their out-fall channels will be leſs liable to ſilt. The new cut below will, in my opinion, be amply ſufficient for all purpoſes; for though propoſed only 40 feet at bottom, yet, according to the proportions given, will be 80 feet at top, at 10 feet depth; whereas the cut above *Scotch Flat Sluice* does not appear to be above 30 feet at bottom, the ſum of all the openings of that ſluice being but 26½ feet wide, and yet through this capacity is diſcharged all the ſpring and down-fall waters from an extenſive flat and upland country. Again, though the ſum of the openings of the propoſed ſluice at F is propoſed only 11 feet wider than that of *Scotch Flat*, yet as the cills thereof will lay at a medium of 2 feet 3½ inches below thoſe of *Scotch Flat*, and about 4 feet lower than *White Kemp*, which is the loweſt of the four upon the marſh wall; that before the water iſſuing at the ſluice F can pen upon the *Scotch Flat*, or the four other ſluices before ſpecified, the capacity of the new ſluice, taking width and depth together, will greatly exceed the ſum of all the reſt put together. I mention thoſe things more particularly, becauſe, for reaſons before given, I look upon all unneceſſary widths, either in the ſluices or drains, to be hurtful, it being to no purpoſe to dig out canals merely for the ſea ſilt to fill up again.

I muſt alſo here mention another advantage to the drainage of the lands dependent on the ſluices beforementioned; and that is, the danger of the loſs of their preſent out-fall; for though the land waters will always find a way to ſea, yet it does not follow that it muſt be at ſuch a perpendicular height or depth as is conſiſtent with the drainage of the lands; this has actually happened in the courſe of a few years to the river at *Boſton* in *Lincolnſhire*; whereas the new out-fall propoſed will be always capable of maintaining its original goodneſs. And the ſame reaſoning will hold with reſpect to all the other levels which ſew into the old harbour of *Rye*.

I am, however, of opinion, that the tides ought never to be ſhut in by the great ſluice ſo as to pen upon the aprons of any of the ſluices for drainage, at a time when any of the levels are under water on occaſion of rains or other down-fall.

With

With respect to the *Winchelsea* channel, as an out-fall sluice, as beforementioned, has been erected thereon, within the compass of a few years, near the town of *Winchelsea*, which being very properly placed for stopping of the tides, I am of opinion that nothing further is necessary than to strengthen the walls from the new canal to this sluice, as before mentioned, and to keep this sluice in repair; and that no additional sluice on the main channel, between the aforesaid and the new canal, can be attended with any benefit to drainage, and will be an impediment to navigation up to the town of *Winchelsea*.

I am further of opinion, that no sluice placed to the east of the town of *Rye*, by way of taking in the tides into the channels, proposed as aforesaid, from the old harbour, can be of any use, because I expect that the first winter after the diversion of the land waters, the mouth of the old harbour will in a great measure, if not totally, be choaked up by the sea.

From my view of the works already undertaken, I find many things not yet compleated, particularly about the harbour's mouth, the pier heads and the wharfing proposed to extend from the piers to the great sluice, and many things that have gone into disrepair through length of time since the work was done, and for want of letting the sea into the harbour sooner; but as those matters are capable of rectification, I shall at present take no further notice thereof, than in my estimate of the expence that will attend it. And, upon the whole, I am of opinion, that when what has been and is now proposed, is duly executed, that there may be made and maintained 20 feet water at spring, and 14 feet water at neap tides, from the sea up to the head of the present canal, and a proportionable depth as before specified up to the towns of *Rye* and *Winchelsea*; and that for vessels, such as those depths of water will suit, will be a safe, useful, and commodious harbour, and therefore advantageous not only to the towns and country adjacent, but to vessels trading through the *British* channel, and therefore useful to trade in general.

London, February 16, 1763. J. SMEATON.

ESTIMATE

An ESTIMATE for compleating the harbour of *Rye*, according to the plan and report of J. SMEATON.

	£.	s.	d.			
To raiſing the eaſt pier head with ſtone 5 feet higher than it now is, and coping the ſame with ſtone, containing 4589 cube feet, at 3s. 6*d.* including cramps, comes to 803*l.* and foi repairing the decayed part, fender piles, &c. 197*l.*; in the whole, - - - -	1000	0	0			
To raiſing the ſtone part of the weſt pier 5 feet high and 4 feet thick, 1080 feet, at 3*s.* 6*d.* 189*l.* and for repairs of fenders, - -	200	0	0			
To compleating and making up the additional part of the weſt pier, between the ſtone-work and new head, and for fixing a capſtan upon the ſaid head for warping out ſhips, - - -	300	0	0			
For repairing and backing up with rough ſtones the wing, wharfing, extending from the eaſt ſtone head into the beach fronting the eaſt, -	300	0	0			
To expences in clearing out the harbour's mouth, ſo as to be 20 feet deep at ſpring tides, - - - - - -	500	0	0			
To 2800 feet running of the wharfing, and ſecuring the banks of the preſent canal from the preſent wharfing to the ſluice, at 2*l.* per foot,	5600	0	0			
To repairs of the wharfing already done, - - -	200	0	0			
To ſecuring the aprons of the ſluice, above and below, with rubble ſtone, containing 3500 tons, at 5*s.* - - - - - -	875	0	0			
To making 4 wharf-wings for preventing the waſh of the water from getting behind the wings of the ſluice, containing 140 feet running, at 2*l.* - - - - - - - - -	280	0	0			
To additional mechaniſm, in order to make the drain-gates riſe with more eaſe; - - - - - - -	250	0	0			
To carpenters and ſmiths work in repairing and ſtrengthening the preſent great gates, ſo as to make them more laſting, - -	100	0	0			
To capping over the piers of the ſluice with *Portland* ſtone, containing 3797 feet, at 3*s.* 6*d.* cramps included, - - -	665	0	0			
To making a timber draw-bridge over the head of the preſent canal, for communicating the road as it now paſſes over the dam from *Rye* to *Haſtings*, - - - - - -	1000	0	0			
				11270	0	0
To digging out the channel from the new canal to *Rye*, containing 261653 yards, at 3*d.* - - - - - - - -	3271	0	0			
To removing the preſent dam, and making ſuch new ones as will be wanted during the progreſs of the work, and making up the banks, at leaſt to the height ſpecified in the plan, - - -	1408	0	0			
To widening and deepening the *Winchelſea* channel, and making up the banks, as per ſcheme, containing 49573 cube yards, at $2\frac{1}{2}$ *d.* -	516	0	0			
			Carried over	16465	0	0

	£. s. d.	£. s. d.
Brought over - -		16465 0 0
To cutting a new canal to the north of the town of *Rye*, from the *Tillingham* channel, at the point D, to the *Rother*, at the point E, being 40 feet bottom, 16 deep, and 9 furlongs in length, containing 249736 cube yards, at 3*d*. - - - - - -	3121 0 0	
To constructing a navigable sluice and bridge upon the aforesaid canal, of 37½ feet clear waterway, at the point F, - - -	1800 0 0	
To erecting a timber bridge across the aforesaid canal for continuing the road from *Rye* to the ferry, - - - -	500 0 0	
To making a dam across the *Rother* below the point E, - -	800 0 0	
To continuing a sea bank or wall from the dam at E, to marsh wall at G.	65 0 0	
To making a dam across the united channels of *Winchelsea* and *Tillingham*, near the new bridge at *Rye*, at K, - - -	800 0 0	
To erecting a navigable sluice upon the *Tillingham* channel, above the ferry, as at H, and making a cross bank, - - -	500 0 0	
To making a new drain 95 *l*. and out-fall sluice for *Wenway Crook* water, 105 *l*. - - - - - - -	200 0 0	
To contingent expences upon the whole, - - - -	2500 0 0	
		£. 26751 0 0

February, 1763. J. SMEATON.

SCHEDULE proposed to be annexed to the Act for finishing the harbour of *Rye*.

Manner how the harbour is to be finished and compleated, subject to alterations, as mentioned in the Act.

THE channel of *Winchelsea*, from the north end of the new canal to the junction of *Tillingham* channel near the town of *Rye*, to be widened, deepened and straitened, so as to be a medium of 50 feet wide in the bottom, each side to batter at the rate of 2 feet horizontal to 1 foot in depth; the bottom to be so disposed as to make a part of a plane regularly inclined, from the lowest sell of *Scotch Flat Sluice* upon the *Rother*, as it was in the month of February, 1763, to the sell of the great sluice upon the new harbour;

harbour; the banks or walls to be ſet at leaſt 40 feet, at a medium, from the brink, and to be raiſed 25 feet at leaſt above the ſell of the great ſluice, to be 6 feet top, to batter 2 and $\frac{1}{2}$ to one towards the canal, and 1 and $\frac{1}{2}$ to 1 landward.

To widen, deepen and ſtraighten the *Tillingham* channel from the point aforeſaid, ſo far upwards as ſhall be neceſſary to come at a proper place of departure into a new canal, next hereafter mentioned.

To make a new cut or canal to the north of the town of *Rye*, from ſome convenient part of the *Tillingham* channel aforeſaid, to ſome convenient point of the river *Rother*, the cut to be 40 feet bottom, to agree with the inclined plane aforeſaid; its ſides to have the ſame batters as the former; it's banks or walls to be raiſed to the ſame height, to have the ſame dimenſions at top, the ſame batters and diſtance as before deſcribed, as far as the croſſing of the preſent turnpike road which leads from *Rye* towards *London*; but if any part of the ground ſhall not be ſufficient to allow the batters, ſlopes and diſtance of the banks, before ſpecified, then the ſides of the canals and banks to be wharfed up or otherwiſe ſupported, ſo as to preſerve the bottom of the canal of the width before ſpecified, and the banks to be made ſufficiently ſtrong to hold in the waters to the ſame height as before ſpecified.

A bridge to be built upon the ſame turnpike road for croſſing the canal, to conſiſt of three arches, one of 13 feet 6 inches wide, the others of 12 feet each; the large opening to be furniſhed with two pair of gates pointed to ſeawards, ſo as to form a navigable lock, and onepair of gates pointed to landward; the other two arches or paſſages to be furniſhed each with one pair of folding or falling gates to ſeaward, and gates to landward. The ſells of thoſe gates to be laid even with the propoſed bottom of the canal at this place.

To fix a dam acroſs the river *Rother*, near below the point where its courſe ſhall be diverted as aforeſaid, and to erect a ſea-wall or bank from the ſaid dam to ſome convenient point eaſtward, upon the preſent ſea-wall of the adjoining marſhes, and to carry another ſea-wall from the ſame dam, weſtward, to abut upon the aforeſaid turnpike road; the ſaid dam and walls to be raiſed to an equal height with the adjoining wall againſt the ſaid marſhes; to be 6 feet at top, and to batter both ways as 2 and $\frac{1}{2}$ to 1.

A navigable ſluice to be fixed acroſs the *Tillingham* channel, at ſome convenient place within half a mile of the bridge. at the ferry near *Rye*, of 13 feet 6 inches in the clear,

 with

with a pair of gates pointing to ſeaward, and another pair to landward, with draw ſhuttles or ſlakers in the latter, and the walls or banks of the *Tillingham* channel, from the ſaid ſluice, downwards, to its junction with the canal before deſcribed, to be heightened in ſuch manner and proportion as is deſcribed for the main channel from the new canal to *Rye.*

A dam to be fixed acroſs the preſent combined channel of *Winchelſea* and *Tillingham*, at or near the preſent new bridge at *Rye*; the top thereof to be made up to the ſame height as propoſed for the aforeſaid new channel from the new canal to *Rye*, and to have the ſame ſlopes as the dam aforementioned, to be erected upon the *Rother.*

The channel of *Winchelſea*, from the preſent canal to *Winchelſea Sluice*, to be widened and deepened, ſo as to be 20 feet in the bottom; to form an inclined plane, ſo as to fall 2 feet towards the new canal, from the ſell of *Winchelſea Sluice*; the batters of it's ſides, the heights and ſlopes of it's walls to be the ſame as propoſed for the new channel from the new canal to *Rye.*

In caſe the diverſion of the land waters ſhall occaſion the out-fall of *Wenway Sluice* to choak up, then a new channel to be cut, and ſluice erected, for the diſcharge of *Wenway Waters*, above the propoſed dam, into the *Rother.*

Proper bridges to be made for communication of the preſent roads.

To CAPTAIN PIGRAM.

SIR,

YOUR favour of the 9th inſtant was duly received, and now comes in courſe to be conſidered. As almoſt two years ſince I was at *Rye* are now gone over, without any progreſs being made in thoſe additional works, which were reported abſolutely neceſſary to be done for preſerving the harbour, even in the ſtate I found it, it now behoves you to take vigorous meaſures, and not be impeded by ſmall matters, leaſt you loſe the benefit intirely of what has been done.

That it is neceſſary forthwith to bring in as much of the back-water as you can procure, appears very evident from what you report, viz. that the new canal is ſwerved up,

up, towards the head, 8 feet higher than when I ſaw it, which is very conformable to what you will find in my report, viz.

" This canal alone, excluſive of the outer harbour, will take in above 200 ſail of
" veſſels, but yet does not contain a ſufficient body of water to produce the neceſſary
" ſcouers below; and furthermore, this part of the canal being liable to ſilt up, by the
" depoſition of mud brought in by the ſea, will, in a few years, be choaked up, and
" rendered intirely uſeleſs; the ſilt being gathered at leaſt 4 feet deep at the head of
" the canal, ſince July laſt, when the harbour was opened. What therefore is *princi-*
" *pally* wanting to compleat what I apprehend to have been the original ſcheme, is to
" bring the land-waters and freſhes of three rivers, that now diſcharge themſelves into
" the old harbour of *Rye*, through the new harbour, by which means the whole will
" be kept clear, as appears to me from the following reaſons, &c."

As I look upon the *Winchelſea* waters alone to be inſufficient to preſerve in the canal a requiſite width of channel ſufficient for navigation, the grand object is to get poſſeſſed of the *Tillingham* water as ſoon as poſſible; the natural courſe of proceeding is this.

1ſt. To ſecure the banks or walls of the *Winchelſea* channel from the head of the new canal to *Winchelſea* ſluice.

2d. To cut through the dam that at preſent divides the new canal from the *Winchelſea* channel.

3d. To raiſe two dams acroſs the *Winchelſea* channel, one juſt below, but as near as poſſible the head of the new canal; the other as near as may be to it's junction to the *Tillingham* channel, by which means you are enabled to dig out the channel, as directed, from the new canal to *Rye*.

4th. This done, you remove the two dams, and, with as much expedition as poſſible, raiſe the dam at *New Bridge* acroſs the united channels.

By this management, you, in the firſt place, become poſſeſſed of the *Winchelſea* waters, towards making a ſcour, and alſo that part of *Winchelſea* channel that lays between the preſent head of the new canal and *Winchelſea* ſluice, to add to your reſervoir, when you pen in the ſea water; and, in the ſecond place, you poſſeſs yourſelf as early as poſſible of the *Tillingham* water, and of the great increaſe of reſervoir that will

follow

follow upon opening this new channel and that of *Tillingham.* With these two you will make something of a figure towards the proposed design, and at the same time bring up vessels to *Rye* by way of the new harbour.

By this method of proceeding the communication of the *Winchelsea* and *Tillingham* waters must necessarily be interrupted during the making this new channel; nor do I know any means of avoiding it, without cutting a fresh channel through fresh grounds, which would not only be a great additional expence upon the undertaking, but only partially remove the objection. If therefore the clamours raised by the seamen and by the country on this occasion are to prevail, I would advise the Commissioners at once to give up the undertaking, and spend no more money upon it; for if the means are not to be used, by which it is to be effected, it is in vain to make any further attempts; but as I can see no material or lasting inconvenience likely to arise herefrom, I will endeavour to satisfy all reasonable and impartial persons on this head.

And first, with respect to the land owners upon the *Winchelsea* channel, those below the sluice will probably expect to be overflown by the tides rising higher upon them from the new harbour than the old; bnt it appears, from my levelling notes, taken when there, that when the tide flowed 19 feet 9 inches upon the beacon or staff, at the head of the new canal, it rose within 8 inches of the same level in the *Winchelsea* channel, on the other side the banks, and that when it rose to 20 feet 3 inches upon the said beacon, it rose within 2 inches of the same level in the *Winchelsea* channel. Hence I conclude, that in the greatest tides there is very little difference, or possibly higher in the *Winchelsea* channel than in the new harbour, correspondent to what is usually observed, that weak tides are much spent by a long and intricate course, but when all obstructions are surmounted by a strong tide, that the motion, thus acquired, will lift the tides to a greater height in a river, at a distance from the sea, than near it's mouth: but however this may be in the present case, from the matters of fact above stated, it appears that a much greater flow of tide is not to be expected from the new harbour than the old.

In regard to the sewage of the low grounds at low water, it is very evident that this will be improved, because the fall sluice at *Winchelsea* will then be nearer it's outfall to low water at sea, and consequently it's course being shortened, it will have more fall in proportion, and thereby penning less dead water upon the apron of the sluice, the water will discharge itself faster through the same openings. It may possibly be objected, that the mud is gathered in the new harbour to a greater height than it's present

prefent bottom, at the fame diftance from the fluice, which will be an obftruction; but the land water will foon cut a channel through the loofe mud.

I take it for granted, that whenever thefe waters are firft turned this way, a channel will be opened through the mud, which, once done, there is no doubt to be made but that the water will not only maintain itfelf a channel through the frefh mud, of as great dimenfions as it does in the folid ground, but will even deepen the whole, on account of it's greater rapidity.

The fame reafons will alfo take place with refpect to the lands that lie upon, or few, by the *Tillingham* channel, both before and after their re-union with the *Winchelfea*; becaufe, before they will have the whole channel to themfelves, and after they will have both a fhorter and a better.

It therefore remains that I give my reafons why I don't think the navigation will be fpoilt up to *Rye Strand.*

The harbour or place where fhips now lie is intirely within the *Tillingham* channel, and which they now find fufficient; it therefore follows, from the eftablifhed laws of nature, that the fame caufes producing the fame effects, the *Tillingham* waters will maintain the fame channel below the new bridge that they do above.

It may be objected, that the united channels below the new bridge, being wider from the union of the two rivers, this channel may grow more fhallow, as well as contract in width! I am of opinion that it will not; for fince there is conftantly matter floating in the water capable of choaking up all the channels, if the land water did not drive it out and keep them open, why does not the *Tillingham* channel widen and grow more fhallow? but fuppofe the channel was to grow fomewhat more fhallow, yet, for the time, it will be wanted the fame expedients might be made ufe of as is done in feveral other channels, viz. a hedgehog to raife the mud occafionally, till the fides have contracted themfelves to proportionable width. Some fmall alteration in point of width may alfo be expected at the old harbour's mouth, but as the effect can only be in proportion to the caufe, if we compare the body of water, either coming down or lodged in that part of the *Winchelfea* channel, from the new bridge to *Winchelfea* fluice, with the whole body at a full fea, we fhall find the proportion fo fmall as to be almoft infenfible in its effects; but if by the objections made by the mafters and owners of fhips at *Rye*, they mean that the prefent channels are not to be diverted or altered till the mouth of the new

harbour

harbour is effectually fcoured, and every thing ready to bring up fhips to the town of *Rye* by the new harbour; as this is in the nature of the thing impoffible to be done but by means of the diverfion of the faid channels, they thereby defire that the effect may precede the caufe, which being contrary to nature, they at once ftrike at the root of the undertaking, and therefore, as I have already faid, if thefe arguments are to prevail, the beft way is to give the thing over at once.

A great deal depends upon the expedition with which thefe works are performed; for if, while the new channels are digging, the new haven is contracting in width, for want of a fufficiency of back water to keep it open, by fuch times as they are compleated, the new haven will be afrefh to dig, and the work become endlefs.

Difference of circumftances alter cafes. Two fummers are now elapfed fince my fcheme was made, and 8 feet more of mud in the new canal; it is therefore not only neceffary to purfue vigorous meafures, but to take fuch methods in performing the work as may the fooneft put it in a ftate of maintaining itfelf; I would therefore, at the firft outfet, advife, that the new channel from the new canal to *Rye* be not dug but 35 feet, or at moft 40 feet bottom, with flopes as fteep as they will ftand, as fuppofe 1 to 1½, according to the quality of the matter, but never fteeper than 1 to 1; fuch a channel will anfwer all the purpofes of navigation effectually; will fave a very confiderable fum in the firft conftruction; will fave a good deal of time, which is now become very valuable, will fooner bring the utility of the undertaking to a proof, and will be as large a channel as the *Tillingham* can in any degree maintain; which will therefore prevent its fwerving and contracting in width, while the other channels are compleating for bringing in the *Rother*; and when that is done, in cafe the rivers themfelves do not make it of the width fufficient, it may be compleated by tide work, after the more neceffary parts of the work are brought to bear. Nor is there any doubt but that in the mean time it will take the *Rother* and *Tillingham* land waters, as the former go all through *Scotch Flat Sluice*, which it has been remarked is no wider, all the paffages taken together, than 26½ feet; and as to the *Tillingham*, its capacity when the tide is checked by the fluice propofed to be built thereon, will be contained in one of the flopes, for even a 35 feet bottom, with the fteepeft batters, will produce a 65 feet top, and a 40 feet bottom, with batters of 1 to 1½, will produce a river 85 feet at the grafs.

It will here be naturally enquired, whether I would build the fluice propofed upon the *Tillingham*, before it is made to communicate with the new harbour? I anfwer, not, for as the tides will go up in the fame manner, whether proceeding from the new harbour or the old, the ufe of that fluice will be entirely to check the tides from coming in too rapidly

rapidly at the great ſluice by having too much room to expand; but as this will not be the caſe till the communication with the *Rother* is made, till then it will be uſeful by enlarging the reſervoir.

With reſpect to the works at the harbour's mouth, you know it was always my opinion, that an attempt to ſtop the beach abſolutely from moving from the weſt towards the eaſt would be a fruitleſs and endleſs taſk; for let the groins be extended to what length they would, they would fill with beach as faſt as they could be raiſed, and the overplus drive over into the harbour's mouth; I therefore thought it beſt to let the beach drive away gradually as it came, and in conſequence that the extenſion of the weſt head could be of no further uſe than to ſteer the beach clear of the eaſt head till the wind came ſo far out to ſouthwards as to tend to heap up the beach upon the ſhore, rather than drive it along the coaſt, which end ſeemed to me very ſufficiently anſwered by the pier as it ſtood when I ſaw it, eſpecially with the low groin extended therefrom ſouthwards; for it always ſeemed to me, that in caſe the pier was carried out further than abſolutely neceſſary for this purpoſe, that the quantity of beach that will always be left ſcattered about the mouth of the harbour, after every ſouth-weſterly gale of wind, as it were in its paſſage, will be too far in the expanded ſpace without the eaſt head, to be carried out by the ſcours, and then a ſoutherly or ſouth-eaſterly gale brings it right into the harbour: theſe have been my notions about this affair, and which have been before expreſſed.

But as I have not yet found any ſolid ground-work, upon which I am able to determine how the ſea will act in all poſſible caſes; and as you have been pleaſed to try the experiment of a different procedure, I would adviſe you not to lower thoſe groins till you are very ſure they are upon the whole hurtful; and if ſo, the thing determines itſelf; conſider alſo, if hurtful to the harbour, how far they may be beneficial to protect the beach from being carried away to the eaſtward of the eaſt pier, or how far that may be protected by other means. It is one thing to adviſe an erection not to be made, and it is another to adviſe its demolition when made, before it has been ſufficiently tried.

You further inform me, that the old timber wharfing, by getting bare, tumbles down faſter than they can put it up new. Let me once more recommend to you the uſe of rubble ſtones for defending the ſides of your harbour inſtead of timber, not walled, but thrown in ſo as to form a natural ſlope. The effect thereof on many repeated trials I have never found to fail; and I may ſay that I ſaved the two piers of *London Bridge*, whereon the great arch reſts, from being undermined, and thereby the arch from falling, the very ſeaſon I was at *Rye*. I am of opinion, that had 300*l.* been applied in time in rub-

ble ſtone behind your eaſt pier, as mentioned in my eſtimate, that it would have ſaved greater expences, and been a laſting repair; but this, as well as ſeveral other derangements that happened in the mean time, I ſuppoſe muſt be imputed to the unſeaſonable ſtoppage of the bill the firſt ſeaſon it was applied for.

I am, with great reſpect to the Commiſſioners,

S I R,

Your moſt humble ſervant,

J. SMEATON.

Auſthorpe, December 29, 1764.

RIVER

RIVER WENT.

Minutes of a view of the river *Went*, by JOHN SMEATON.

HAVING taken a view of the river *Went*, *Yorkſhire*, from *Went's Mouth* to *Norton Mills*, there appears to me a ſufficiency of fall for draining not only the valley of the river *Went*, but of thoſe lands that have their ſewage into the ſame, and which appear to be of a very conſiderable extent. It appears to me, alſo, that the principal defects of the preſent drainage, ariſes from the great crookedneſs of the river, joined to its being too ſhallow, and a general want of capacity for taking off the water from ſo great a tract of country; the out-fall ſluice is alſo of too ſmall a capacity for the drainage of ſuch an extent of country, but ſeems nearly adequate to the preſent drain; the mechaniſm of its preſent doors, however, is very defective, and they are too low. The river *Dunn*'s water having over-topped the ſame, the banks near the ſluice, which ought to defend the valley of the *Went* from the floods of the *Dunn*, being too low and out of repair, have ſuffered great quantities of water in the late floods to paſs into the ſame. The drainage of the *Went's Valley* is further annoyed by an influx from the river *Dunn* in time of great floods, through a low ſlade of ground between *Braſit Common* and *Flaxley Carr*, and from thence proceeds down by way of a drain called the *Fleet* into *Went*, a little above *Topham Ferry*; for as *Braſit Common* is frequently overflowed by the land floods of the *Dunn*, (and ſometimes even by high tides, according to my information,) and as *Aſh Carr*, which borders upon *Braſit Common*, and is the higheſt part of the ſlade, lays lower than the ſurface of the dam in high floods, the water makes its way through the drains and hedges in great quantities into *Flaxley Carr*, and from thence by the *Fleet Drain* into the *Went* as aforeſaid. There ſeems to have been formerly ſome attempts to have prevented the water of the *Dunn* from taking this courſe, by raiſing a fence bank ſomewhat more conſiderable than common, between *Aſh Carr* and the incloſures that lay eaſt and north-eaſt thereof, which ſo far at preſent anſwers the purpoſe, that by raiſing dams with ſods, &c. in the gateways and low places, a great deal of water was prevented from paſſing, that otherwiſe would have paſſed this way during the great floods, laſt Chriſtmas; and, was this bank raiſed, ſo as to be of ſufficient height and ſtrength, would effectually anſwer the purpoſe; but the ſame purpoſe would be more conveniently anſwered by conſtructing a new bank, with proper tunnels, for the drain acroſs the head or ſouth end of *Aſh Carr*, from the incloſed ground that lays upon the weſt ſide thereof, and abutting upon *Braſit Common*, extending the ſame along or paral-

lel to the ſouth hedge of the incloſure, on the eaſt ſide of *Aſh Carr*, which alſo abuts upon *Braſit Common*, to the ſide of *Braſit Fields*, being in length, by eſtimation, about 250 yards: this bank, in one poſition or other, not only appears neceſſary for ſecuring the drainage of the *Went's Valley*, but will greatly improve that of a conſiderable tract of land laying in the ſlade aforeſaid, particularly about *Flaxley Carr*, which, except a part of the top waters which are run off down the *Fleet* into *Went*, and by another drain leading to the outſide of *Syke Houſe Bank* to the ſouth end thereof into the *Dunn*, depends altogether upon a ſmall tunnel called *Hell Wicket Clough*, no more than 8 inches by 12¼, for running off their bottom waters through *Syke Houſe Bank* into the internal drains, and thence into the *Dunn* by *Black Sea Clough*, which clough runs three days on the decline of a flood before *Hell Wicket Clough* is opened. It further appears to me, that the drainage of *Braſit Common*, and the lands dependent thereon, will receive no prejudice by the bank before propoſed, becauſe *Braſit Common* lays ſeveral feet lower than *Aſh Carr*, both which drain the *contrary* way, or ſouthward into the *Dunn*, the preſent fence bank before mentioned being the line of partition of the two drainages, at all times, except in extraordinary floods as aforeſaid.

Although from this view now taken, I am convinced of the practicability of draining the valley of the *Went*, yet the depth and capacity of its main drain, together with the requiſite height, and dimenſions of its banks and ſluice, cannot be aſcertained without an actual level taken thereof; and, in order to aſcertain the quantity of land concerned in this drainage, as well as the general directions and length of the drains to be new conſtructed or amended, and thereby to come at a correct eſtimate of the ſame, it will be neceſſary to take an actual ſurvey of the river *Went*, from its mouth to *Norton Mill*, deſcribing the banks, ſluice, and main drains that fall into the ſame, upon a ſufficient ſcale to expreſs the particular loops of the river; and alſo an outring or flood line of ſuch parts of the ſeveral lands that drain into *Went*, that are liable to be flooded thereby, or for want of a ſufficient fall into the ſame; which outring does not need to be traced with that correctneſs, that the river itſelf ought to be laid down, but preſerving, however, the general bearing between the river and its correſpondent part of the outline. The taking of the levels I can myſelf undertake, if the gentlemen concerned deſire it, the ſurveying part I would recommend to be done by a ſkilful land ſurveyor.

Womerſley, 31ſt March, 1764. J. SMEATON.

N. B. As the preſent river is wanting in capacity, and its courſe ſo meandering that it is likely to meaſure by its loops double the right line, I apprehend it will be leſs

expence

expence to make a new cut the greatest part of the length, than to sufficiently enlarge the present river, which cut may be so contrived as to strike a general mean between the properties.

MINUTES taken upon the River *Went*, in levelling the same, from the River *Dunn*, at *Went's Mouth*, to *Norton Mills*, the 7th, 8th, and 9th of May, 1764, by JOHN SMEATON.

Places of observation.	Rise of the river's surface.	Widths taken at promiscuous places.	Depths taken at promiscuous places.	Heights of lands above the water's surface.	Rise of the last winter's flood above the river's present surface.
	Ft. In.				
From the surface of the river *Dunn* to the threshold of *Went's* doors, which was 7½ inches under the water's surface there, - - - -	1 5½	Bridge 14 9 other places from 10 to 18	— —	Near the *Dunn* 11 9	Floods of *Dunn* 13 2
From *Went's* doors to *Hooden Dyke*, - - - -	0 9	from 12 to 18	from 0 8 to 3 0	mean height 6 to 5½	*Went's* floods about 6 feet.
From *Hooden Dyke* to *Bawn Croft*, - - - -	3 4½	from 12 to 19	from 3 0 to 1 3	from 4 0 to 1 6	from 4 0 to 3 7
From *Bawn Croft* to *Topham Ferry*, - - - -	0 9½	15 0 bridge 14 2	from 1 8 to 2 0	— —	— —
From *Topham Ferry* to *Lake's Mouth*, - -	3 6½	from 14 0 to 16 0	from 4 0 to 2 0	from 1 6 to 1 2	from 2 6 to 3 0
From *Lake's Mouth* to *Clough Bridge*, at the low corner of *Norton Common*, -	1 9	from 13 0 to 14 0	from 3 0 to 1 2	from 1 3 to 0 6	from 3 0 to 2 6
From *Clough Bridge* to the departure of the *Went* from *Stubb's Common*, -	2 4½	from 16 0 to 15 0	from 1 10 to 1 0	from 0 6 to 2 6	— 2 6
From *Stubb's Common* to *Norton Bridge*, - -	3 7	from 9 0 to 16 0	from 1 0 to 1 8	from 2 0 to 3 0	from 2 6 to 3 0
From *Norton Bridge* to the floor of *Norton Mill Race*,	1 4½	double course.	— —	from 4 0 to 3 0	from 4 0 to 3 0
From the river *Dunn* to *Norton Mill*, - -	19 0				

Hence

Hence it appears, that from the floor of *Norton Mill Race*, to the furface of the river *Went* at *Clough Bridge*, there is a fall of 7 feet 4 inches, and from thence to the threfhold of *Went* doors a fall of 10 feet 10 inches, which added together make a fall of 18 feet 2 inches from the floor of *Norton Mill* to the threfhold of *Went* doors, and from thence to the furface of the *Dunn*, there was a fall of 10 inches; but as it was a neap tide, and not then low water, I fuppofe the *Dunn* would ebb a foot lower, fo that from the tail of *Norton Mill* to low water in the river *Dunn* at *Went's Mouth* at a neap tide, in fummer, we may reckon a fall of 20 feet.

The dimenfions of the fluice called *Went's* doors, are as follow:

	feet.	inches.
The width between the walls at top is - - -	12	0
Ditto at bottom - - - -	10	0
The width of the opening between the gates at top is - -	8	7
Ditto at bottom - - - - - -	7	3

WOMERSLEY

WOMERSLEY DRAINAGE.

The REPORT of JOHN SMEATON, Engineer, concerning the Drainage of the low grounds in the manor of *Womersley*, belonging to STANHOPE HARVEY, Esq;

HAVING taken a view of the lordship of *Womersley*, with respect to the drainage thereof, the 16th and 17th of July, 1764, it appears to me as follows.

1st. That the middle of the manor, through which the drain called *Bradley Dyke* passes, is in general the lowest part thereof.

2d. My own observation also agrees with information, that the piece of ground called *Bradley*, is the most liable to be flooded of any in the lordship.

3d. That from the run of the water in *Bradley Dyke*, which in many places is pretty quick, at the same time that this drain is narrow, shallow, crooked, and much obstructed, there seems to be a fall of several feet in the course thereof from *Bradley* to the brook called *Lake*.

4th. That there is also a considerable fall from the mouth of *Bradley Dyke*, to the beginning of Mr. YARBOROUGH's lands, bordering thereupon at the *Calf Garths*.

5th. That the sewer called *Blowell*, which in general skirts the lordship on the north, and falls into *Lake* at the eastermost point thereof, is very well calculated to answer the purpose of a catch-water drain, to carry off the barrier waters, without suffering them to pass into the internal parts of the manor; but passing in general through higher lands seems not well adapted for a main drain, except for some particular parts, which will hereafter be pointed out.

6th. That the rivulet called the *Beck*, whose continuation after it joins *Bradley Dyke* is called *Lake*, and which makes its way through the southern side of the lordship, is in like manner well calculated for a catch-water drain; but as the *Beck* likewise passes through higher lands, and also carries the springs and flood water from the upland country, it is therefore less adapted for the purposes of a main drain for the interior parts of the manor.

Hence

Hence I am of opinion, that the lordſhip in general will be drained in the beſt manner by a middle drain, calculated more effectually to anſwer the purpoſes of the ſewer called *Bradley Dyke*.

In order to give this drain all the conſequence poſſible, I would propoſe its out-fall to be as low as may be, that the declivity in the *Lake* ariſing from its being loaded with the upland waters, as well as from its crookedneſs and want of dreſſing, may be in a great meaſure avoided. For this purpoſe, I would recommend that the out-fall of the new drain be carried down to the eaſtermoſt part of an incloſure, called *Old Ing Spring*, that is, to the commencement of Mr. YARBOROUGH's lands, which begin with the *Calf Garth* next adjoining; from this point I would propoſe to carry the new drain to *Bradley*, as much as may be in a right line, without interfering with other property, to paſs as much as may be through the loweſt grounds, and ſo as to be as central as poſſible; with this view I would propoſe to carry it from the eaſtermoſt point of *Old Ing Spring*, marked in the plan *a*, obliquely for a few rods till it meets the hedge-row between the *Old Ing* and *Old Ing Spring*, and to follow that hedge-row to *b*, from thence to paſs in a ſtraight line to the ſouth-eaſt corner of the *Sodgels* at *c*, to follow the ſouth hedge thereof to *d*; from thence in a ſtraight line through *Bell Fields*, *Stocking Pohill Spring*, and *Stockings*, to the ſouth-weſt corner of *Ox Stockings*, between *Grayſon Cloſe* and *Bradley Dyke* at *e*; from thence in a ſtraight line croſs *Broad Oak Spring Cloſes* and *Broad Oak Spring*, to the point *f*, between Mr. SAVILLE and Lady BELT's lands; from thence in a right line croſs *Hodſhon Crofts* to the road, and to croſs *Bradly Dyke*, a little above *Bradley Bridge*, to the *Sodgells*, at *g*; and from thence in a right line, ſo as to avoid *Bradley Dyke*, into *Bradley*, at the eaſt corner thereof at *h*; from hence branches may be carried at diſcretion to the more remote parts of the lordſhip, as for example, one from *h*, acroſs *Bradley* weſtward, to *i*, and from thence croſs low moor to *k*, where it will receive the waters from the ſprings riſing near that point, and alſo will conveniently receive the drainage from *Northings*. Another branch may be carried from the ſaid point *h*, croſs *Bradley* north, through *Pipper Carr*, and the reſt of *Woodhall Farm*, to the point *l*, where it is calculated to receive the down-fall waters from the large piece of low ground called *Gale*.

With reſpect to *Blowell*, the *Beck*, and *Lake*, I would adviſe them to be continued in their preſent courſe, and their banks to be made up, and ſtrengthened where neceſſary, towards the interior parts of the lordſhip, in order to keep out the barrier waters from penetrating thither, and thereby not only contributing to flood the lands, but to load the internal drain.

The

The bottom of the propofed drain at its out-fall, I would advife to be made as deep as the bottom of the *Lake* thereabouts when fcoured, and to be carried upon a dead level to about the length of *Stocking Pohill Spring*; from thence to advance upwards upon a regular inclined plane, fo as to be full 5 feet deep on entering *Bradley* at the point *b*, to be 6 feet wide in the bottom, and the fides to flope or batter 1 foot backwards in 1 foot high; fo that fuppofing the mean depth to be 6 feet, it will be 18 feet wide at top, and there will be 8 cube yards in 1 yard running, and in every acre of 28 yards long 224 cube yards, which at $1\frac{1}{2}d.$ per yard will coft 28*s.* an acre, or 1*s.* per yard running; that is, 88*l.* per mile, and for 2 miles and 1 furlong, which is the length of the propofed drain from the point *a* at *Lake*, to *b* in *Bradley*, will coft 187*l.* exclufive of clearing the ground of wood and roots, and exclufive of fuch bridges as may be neceffary where the roads crofs the fame, which are four in number.

The branch drains need not be above 4 feet bottom, carried upon a regular inclined plane, fo as to be at their upper end at leaft 4 feet below the furface of the lands to be drained thereby.

That part of the lordfhip about *Wye Lands*, *Kidcoats*, &c. which now drain into *Blowell*, will drain much better into the new propofed drain, by a crofs cut from *South-Lane*, through *Katele's Crofts*, to the drain between *Bell Fields* and *Hare Springs*; but the lands lying more eaftward about *Mitchel-Lane*, may continue to drain into *Blowell*, being by this road nearer this out-fall, provided the obftructions between *Hedfham Garths*, where this drainage comes in, and the out-fall of *Blowell* into *Lake* are effectually remedied, and that drain deepened from the bottom of *Warfield Wood* upwards to the faid point, in which fpace a good deal of fall is at prefent loft.

Thefe methods fteadily purfued, and ftrictly adhered to, will in my opinion put the lordfhip in as good a capacity of drainage as it is capable of, and which will be fully effected when the river *Went* is made a fufficient fewer for the general drainage of the lands lying thereupon.

N. B. The bufinefs herein attended to is the main drain and the diverfion of the barrier waters; but it muft be underftood, that the benefit arifing therefrom cannot fully take place till the fmaller ditches and fewers that divide and interfect the lands are thoroughly fcoured, and fuch further crofs cuts made to lead the water from low places by the moft direct road into the main drain, as experience and further obfervation fhall fhew to be neceffary.

Womerfley, 18th July, 1764. J. SMEATON.

MISTERTON SAS AND SNOW SEWER.

The REPORT of JOHN SMEATON, Engineer, upon the cafe of *Mifterton Sas* and *Snow Sewer Drain*, belonging to the honourable the Participants of *Hatfield Chace*, from a view taken thereof 14th Auguft 1764.

MISTERTON SAS is the out-fall fluice of the river *Idle*, built upon *Vicar's Dyke*, about half a mile from the *Trent*. This fluice is furnifhed with two pair of doors, both pointed towards the *Trent*, fo as to compofe a lock for navigation of veffels, ferving them to pen from the tide water into the drain, and thereby occafion either pair of the doors to be fhut. The neat width of this fluice is 17 feet 8 inches, and its height above its threfhold a little more than 16 feet. The queftion concerning it is, as I apprehend, whether an addition of water-way at the *Sas*, in time of floods, will be of fervice in reducing the height, and confequently the weight and preffure of the water at thofe times againft the great bank called *Vicar's Dyke Bank*, which defends the level of *Hatfield Chace* againft the floods of the river *Idle*.

OBSERVATIONS.

1ft. The time that I was at the *Sas* the tide was out, all the doors open, and the land water had its free courfe through the fame; the depth of water running over the threfhold of the doors to landward was 4 feet 7 inches, and the water's furface had a fall from head to tail of the fluice of above $4\frac{1}{2}$ inches, confequently the threfhold of the doors to Trentward were below the furface of the tail water 4 feet $2\frac{1}{2}$ inches.

2d. Being met at the *Sas* by Mr. WILLIAM CROMPTON, he having made feveral exact obfervations upon the ftate of the waters here during the courfe of laft winter, informed me that the 21ft of May laft (which was the day before the moon quartered) he obferved that the tide rofe at the *Trent* 5 feet before it fenfibly rofe at the *Sas*, the tail water at the *Sas* being then the fame height as this day, viz. 10 feet 10 inches below the S. E. corner of the land wall at the *Sas*; now had there been no run of water through the *Sas*, then the water would have been upon a level from the *Trent* to the *Sas*, and of confequence,

consequence, it would have appeared that the threshold of the sluice would have been $9\frac{1}{2}$ inches higher than low water mark at the *Trent*; but as the run of water through the sluice was then considerable, as it was this day, it follows that as soon as the water begun to find any stoppage at the sluice to its discharge into the tail drain by the rising of the tide, that the water at the sluice would begin to swell or rise, though it still preserved its motion downwards, and consequently that it would begin to swell before the water of the *Trent* was got up to the same level; now if we allow 2 or 3 inches for this declivity from the *Sas* to the *Trent*, which must be added to the former $9\frac{1}{2}$, we shall have about 12 inches that the thresholds of the sluice lay higher than low water mark at the *Trent*.

3d. Mr. CROMPTON also shewed me a mark that the land waters were at on the head of the sluice the day before the bank broke at *Idle Stop* last winter. This mark I found to be 5 feet 5 inches above the present head water, and consequently (allowing $4\frac{1}{2}$ declivity on on the tail) 5 feet $9\frac{1}{2}$ inches above the present tail water. He also shewed me a mark, being the height of the water then in the tail of the *Sas*, when the doors were open and running with a full bore; and this mark I found to be 5 feet $1\frac{1}{2}$ inch above the tail water, consequently the fall of water at the *Sas* was then at its greatest stream 8 inches.

4th. The width of *Vicar's Dyke*, at a medium between the *Sas* and *Idle Stop*, was about 38 feet at the water line, the depth at a medium from 3 to 4 feet, and the water having a smart run all the way, I suppose by estimate that the fall of water from *Idle Stop* to *Misterton Sas* was at least 1 foot per mile; that is between 3 and 4 feet, as I estimate the distance between three and four miles.

DEDUCTIONS.

AS it appears from the preceding observations, that the pen or head of water at *Misterton Sas*, occasioned by want of capacity, never exceeded 8 inches in the greatest extremes of floods; hence it would seem that the flood water was never raised more than 8 inches higher than it would otherwise have been, had the *Sas* been as wide as the river; and this conclusion would be quite just, in case the flood water had been confined on both sides, so as to be obliged to go off as fast as it came down; but as it was at liberty to

 spread

ſpread over the lands, where it did not find a paſſage to its out-fall ſo faſt as it came down, it muſt keep accumulating till the diſcharge was equal to the influx.

Now it muſt be allowed that had the *Sas* been of a greater capacity, it would have run a greater quantity of water upon a given declivity; conſequently, from the firſt approach of floods by continually running more water, the accumulation would have been leſs, and the riſe of water leſs againſt the banks, which in all probability would have preſerved them from breaking at *Idle Stop*. It is by no means however hence to be inferred, that though the ſluice had been as wide as the river, that the floods would have been carried off as faſt as they came; for, in the firſt place, whenever the *Trent* floods or tides over-rode the land waters, the ſluice could not run at all, let its capacity be what it would; and at other times, as the effects depend jointly upon the capacity of the ſluice to diſcharge, and upon the drain to bring the waters to it; and as *Vicar's Dyke* appears to be defective in point of depth, it muſt have had a conſiderable ſhare in the obſtruction: for as from obſervation the 4th, there appears a conſiderable fall from *Idle Stop* to the *Sas*, this cannot be otherwiſe occaſioned than by a riſe of the river's bottom, which thereby holds up the water, and muſt obſtruct its free paſſage in all degrees of floods: whether this obſtruction has gradually aroſe by means of weeds, &c. or it has been originally made ſo, may be a queſtion; but we may reaſonably ſuppoſe it was originally made ſo; for was this part of the river deepened, it would draw off the water from the higher parts of the river in dry ſeaſons to a greater degree, ſo as to incommode the navigation, and perhaps at ſome times to put an entire ſtop thereto for want of water over the ſhoals above.

Upon the whole, then, I look upon the enlargement of the water-way at *Miſterton Sas*, to be an adviſeable ſtep, and that it may be done in a proper degree relative to the drain, even upon a ſuppoſition that it was deep enough, we are to enquire what capacity the ſluice ought to have had.

The width of the drain 38 feet at the water line, ſuppoſing it to carry 3 feet water, it will batter 3 feet each ſide, and will have a 32 feet bottom: this ought to have been the width of the water-way, ſuppoſing the threſholds laid as low as the water-mark. The greateſt extremes of floods riſe per obſervation 10 feet above the threſholds of the ſluice, and conſequently 11 feet above low water mark, ſo that 11 feet multiplied by 32, the proper width, given 352 feet area, for the water-way; but 10 feet the preſent height, multiplied by 17 feet 8 inches, preſent width, gives 177 feet area nearly; which, being nearly half of the former, it ſhows that the preſent water-way ſhould be doubled, if laid at the ſame depth.

This

This enlargement may be made three ways:

1ſt. By four draw-gates of 4 feet 6 inches wide each. 2d. By two pair of pointed doors, placed near together, one pair pointed to *Trent*, the other landwards, which latter may be gaged to the height requiſite for navigation.

3d. By one pair of doors pointed to *Trent*, and by a fixed over-fall or weir, gaged to the height neceſſary for navigation.

The doors in the 2d and 3d method may be the ſame width as the preſent *Sas*, the threſhold being laid at the ſame depth, or about 16 feet wide if laid down to low water mark; but in the 3d method, ſuppoſing the height neceſſary for navigation to be 5 feet above the preſent cill, then the length of the crown of the over-fall muſt be 35 feet, for then when the floods riſe 5 feet above the top thereof, there will be 175 feet area of water-way, which, with 177 feet at the *Sas*, will be 352 feet, as required.

The firſt method has preference in point of expence, but the gates will want opening on the approach, and ſhutting on the decline of a flood; and as theſe are not ſudden, or of very ſhort continuance, may eaſily be done.

The ſecond method will be nearly as cheap as the firſt, and will need attending at the ſame time.

The third method will be ſomewhat more expenſive than either of the former; will be preferable on account of needing no attendance; will do the ſame office on the extremes of floods; but will be of leſs ſervice in diſcharging the water on the decline of floods; which, though of no immediate conſequence to the banks when below a certain height, yet in caſe of ſucceeding rains, the nearer the former are run off, the more room for thoſe that follow.

That the third method will be inferior in point of diſcharging water on the decline of floods, appears thus: ſuppoſe the water reduced ſo as to make 1 foot over the crown of the weir, its area of diſcharge will then be 35 feet, whereas it would make 6 feet over the threſhold of the gates or doors, and upon 17 feet 8 inches wide, 106 feet area: the weir indeed is not confined to 35 feet long, but in this caſe it would be required nearly three times as long to do the ſame thing.

The ready diſcharge of the water on decline of floods will be very beneficial to drainage of the lands, which drain into *Idle* or *Vicar's Dyke*, and therefore ought to [con]tribute if done on that principle.

ON SNOW SEWER.

THIS drain leads the down-fall water from that part of the level adjacent to *Idle Stop*, &c. on the fouth fide of the ifle of *Axholme*, to a place called *Ferry*, where there is a fluice called *Ferry Sluice*, by means of which the water of this fewer is difcharged into the river *Trent*, and is the higheft fluice upon the river belonging to this level, and confequently has the leaft natural fall; it was however neceffary, on account of the drainage of that part of the level laying on the fouth fide of the ifland, the high land of which abuts eaftward on the river *Trent*, and thereby prevents a natural communication of internal drains to carry the waters of thefe parts to a lower point upon the *Trent*, without carrying them a great way round about the weft end of the ifland.

This drain is from 15 to 20 feet wide at the water line, and when I was there carried a full body of water, which at three miles diftant from the fluice had for the moft part a flow run, except in fome places where it appeared to be fanded; there the motion was fomewhat more lively; but as the drain was in moft places horfe belly deep, quite free from weeds, and no capital obftructions, there appeared upon the whole to be no remarkable lefs of fall. As we approached nearer the fluice, the water was in a manner ftagnant, the doors being fhut by the tide: in this ftate, the water was juft beginning to get upon the furface of the commons from a mile to a mile and a half weft of the fluice, which hence appears to be the loweft. I obferved at the fame time that the water was 3 feet 6 inches deep upon the land apron of the fluice.

The fluice confifts of two doors of 6 feet water-way each; but the tide being in, and the fluice-keeper abfent, there was no coming to the knowledge at this time how the threfholds of the fluice lay with refpect to low water mark in the *Trent*; accordingly orders were given that this fhould be taken at a proper opportunity, and the following were in confequence fent me.

	Feet.	Inches.
Above the threfhold, - - -	2	2
On the floor, - - - -	2	9
The fall of water, - - -	5	9

Mr. Forster fufpecting the above might not be rightly taken, defired me to go over again, but, being engaged at that time, fent my clerk, who took the levels the 9th of September,

tember, being the day before the full moon, and consequently between the neap and spring tides: his account was

	Feet.	Inches.
The surface of the water in the *Trent* at low water, above the top of the threshold, - - - - - - -	0	2
Thickness of water going over the threshold, - - -	0	6
He was further informed that at dead of neap the surface of the *Trent*, at low water, was lower by - - - - -	0	6

From the last observations it appears, that the threshold of *Ferry Sluice* lays higher than low water mark at dead of neap (which here it seems makes the lowest water) by 4 inches; and allowing 7 inches for the height of the threshold above the floor, (according to the former observations) and taking this from 3 feet 6 inches (measured by myself) upon the land apron, there will remain 2 feet 11 inches descent from the surface of the lowest lands to the threshold of the sluice, and 3 feet 3 inches from ditto to low water mark, neap tides. Hence it appears, that as the fall is but barely sufficient to furnish the means of drainage, the whole ought to be constructed upon the nicest principles, and kept in exact order.

It does not appear to me, that any great matters can be done till the sluice is rebuilt, further than an effectual scouring of the drain, and deepening where found necessary; and if banks of 2½ or 3 feet high were raised against the low commons, it would prevent their being overflowed by the water coming down from the westward, when the *Trent* floods over-ride the drain, and keep the doors constantly shut; but then tunnels with valves next the drain must be laid through such banks, to take off the down-fall from the commons, where the water of the drain becomes lower, otherwise such banks will be a means of retaining the water upon the lands, as well as in preventing their being overflowed. A further temporary expedient might be, to turn as much of the water as may be from the western parts, towards *Austhorpe Sluices*, which, laying lower upon the *Trent*, afford a better fall.

When *Ferry Sluice* is rebuilt I would advise its floor to be laid lower by 1 foot 6 inches, that is, 1 foot 2 inches below low water mark at neap tides, and to be made at least 15 feet clear water-way, to be shut by a pair of pointed doors.

I know this practice will be opposed, upon a supposition, that being laid so low it will not run so long, and will be more liable to warp.

But it is very plain, that was the orifice a mile deep, it would always run when the water within was higher than the water without, and that at all other times the doors would be ſhut; and this will equally be the caſe if laid high, but with this difference, that by being dammed up by the floor and threſhold, it will not run when the water of the drain is lower than the threſhold, though higher than that of the river. To make the advantage clear, let us ſuppoſe 1 foot water going over the threſhold of the preſent ſluice, which being 12 feet water-way, the ſection of the column of water paſſing will be 12 ſquare feet; now ſuppoſe the water at the ſame height within, and the floor 1 foot 6 inches deeper, then it would run with the ſame velocity in a column 2 feet 6 inches in thickneſs and 12 feet wide, which makes 30 feet area of the column; ſo that in this caſe the ſluice would run as much in one tide as in the other it would run in $2\frac{1}{2}$ tides; but if the width is increaſed to 15 feet, the area will be $37\frac{1}{2}$ feet, ſo that it will then run more water in one tide than the preſent one in three. Again, when the preſent ſluice is run dry, there will be a column of 1 foot 2 inches thick upon the threſhold of the new, whoſe area will be $17\frac{1}{2}$ ſquare feet, which will vent as much water as the preſent ſluice will do when it has 11 inches water upon its cill; ſo that the conſtruction propoſed will not only, at all heights of the water, run much more in quantity, and thereby vent the water quicker, but run it down to a lower ſurface than it poſſibly can be by the preſent conſtruction.

With reſpect to ways, ſuppoſe the old and new ſluice both warped up to the ſame height to both without, and the water at the ſame height to both within, that is both to act from the ſame drain; it is plain that the old ſluice cannot act till a channel is made through the warp, whoſe bottom is lower than the ſurface of the water in the drain; it is alſo plain that the new one will begin to act at the ſame time; the only difference will be, that as the warp will lay 18 inches deeper againſt the doors of one than the others, there may be ſome little more trouble in clearing the warp from before the doors, ſo as to ſuffer them to open at the very firſt ſtarting; but after each has begun to run, and cleared away a part of their warp, the new ſluice will always have the advantage of the old one, becauſe, by carrying a greater body of water, it will open its channel quicker and more effectually keep it open at low water, ſo long as it continues to run.

The ſluice being thus conſtructed, it will be neceſſary to deepen the drain, making the bottom 15 feet wide, and to carry it as near as poſſible upon a dead level with the threſhold for 2 miles; from thence it may be regularly inclined towards its head: this being done, in my opinion, it will do its duty without ſuffering any of the lands to be overflowed by the *Trent*.

Auſthorpe, 19th September, 1764. J. Smeaton.

EARL OF KINNOUL's LANDS.

The REPORT of JOHN SMEATON, Engineer, concerning the Works for the Defence of the Lands of the Right Honourable the Earl of KINNOUL, laying upon the Rivers *Ammon* and *Tay*, *North Britain*.

1st. IT appears to me that the greateſt part of the damage done by floods upon theſe lands, is owing to the ſhallow channel of the river *Ammon*, and the inſufficiency of its banks.

2d. That, in order to cure theſe defects, it will be neceſſary to carry a bank from a point of land marked out, about half an *Engliſh* mile above *Ammon Bridge* down to the eaſt abutment wall of that bridge, and from the ſaid eaſt abutment to carry a bank coaſting the eaſt ſide of the river *Ammon*, at a proper diſtance to the point of land laying between the mouth of the *Ammon* and the *Tay*, which bank ought at a medium to be about 4 feet high and about 20 feet of baſe, the ſlopes to be ſodded on both ſides, or that next the river to be covered with large gravel.

3d. That as the aforeſaid work will be of equal and immediate advantage to the grounds now liable to be flooded by the waters overflowing the banks of the *Ammon*, which are without the border of the eſtate of the Earl of KINNOUL, (and upon which the ſaid banks are propoſed to be made) therefore the proprietors to be at a joint expence with the Earl of KINNOUL for the compleating thereof.

4th. But in caſe the ſaid proprietors do not chuſe to be at their proportion of expence, then I would adviſe the Earl of KINNOUL to make good the breach that has been made in the land contiguous to the bulwark erected at the end of the new road leading from *Perth* to *Ammon Bridge*, and to make the whole effectual, to take down the remains of the preſent bulwark, and to make the whole of rough or rubble ſtone from the quarry, added to the preſent materials thrown together bank faſhion, ſo as to ſlope $1\frac{1}{2}$ feet baſe to 1 foot perpendicular towards *Ammon Bridge*, and $2\frac{1}{2}$ feet baſe to 1 foot perpendicular on the ſide next *Perth*, to make the ſame 2 feet lower than the ſurface of the ground on which the ſaid bulwark abuts in the middle between the abutments, but to raiſe the ſame ſomewhat higher than the ſaid ſurface at the ends where the bulwark abuts upon the ſame, and to extend the rubble work 1 rod at each end on the plain ſurface, and alſo to

line the banks or abutments with rubble for 1 rod above, and 2 rods below the bulwark at each end; which ſaid bulwark is intended to confine the waters of the *Ammon* or *Tay* in moderate ſpeats from flowing down the old road, but in high floods to break the rapidity of the current, and to admit the ſame to have an eaſy paſſage over the bulwark.

5th. In regard to the great bulwark, which was erected at the joint expence of the Earl of KINNOUL and the town of *Perth*, in order to preſerve and regain the lands from the incroachments of the river before which it has been raiſed, I am of opinion that the lands might have been ſecured in a much eaſier and cheaper method, as hereafter deſcribed, and with reſpect to the regaining of lands they could never be worth the purchaſe: it further appears to be built of very bad ſtone, and therefore will be ſubject to a conſiderable annual repair, greater than will ſupport the banks intended to be ſupported thereby; yet as ſome good has been produced from it, though not adequate to the expence of building or maintaining it, yet I would not adviſe any eraſement thereof, but to leave the ſame to ſuch events as the floods and weather may produce, and which in a ſtate of rubbiſh, by keeping the channel of the river at a diſtance, will tend to leſſen the repairs, which otherwiſe might be neceſſary on the ſaid banks; and whenever the river ſhall begin hereafter to make any depredations on the land, to apply the cure immediately to the part affected, which I would adviſe to be done in the following manner:

Let a quantity of rubble ſtone be brought from the quarry, the more angular, rough, and irregular the better, and at a medium as big as a large cabbage; let as much be thrown up againſt the broken place (almoſt as ſteep as it will lay) as will form a natural ſlope againſt the bank as high as ordinary floods reach, or as the ſurface of the lands where lower, ſloping away the land above the rubble where higher, obſerving to avoid all jetties and protuberances as much as may be, ſo as to give the water as free a paſſage as poſſible. In general I would adviſe my Lord KINNOUL, in caſe of breaches or incroachments upon the land by this or any other river, not to have recourſe to jetties, or walls of maſonry, but to line the banks with rubble thrown in, ſo as to form a natural ſlope, and the length of the work the nearer it is to a parallel direction with the current the better, by this means the quantity of materials neceſſary to form a jetty, breakwater, or bulwark (which being deſigned to reſiſt and oppoſe the current muſt be made ſtronger) being diſpoſed along the face of the bank, will in general be ſufficient to defend the whole length that could be expected to be effected by the jetty; and with this difference, that the edge formed by the jetty itſelf, generally forms a pit or incroachment upon the land juſt below; whereas the work diſpoſed in a parallel direction to the current equally protects and equally reſiſts; ſo that the wreck and ſullage of the river in time filling up the

interſtices

interſtices of the rubble makes it grow firmer, whereas the conſtant action of the current upon the weakeſt part of a bulwark or jetty, viz. the termination thereof, puts it in a conſtant ſtate of waſte and decay.

By the application of rubble we have ſtopped the moſt formidable breaches where the river has had its courſe through, by means thereof we ſecure our banks and the aprons of our locks and dams upon the river *Calder*, over which laſt the water in time of floods has much greater rapidity than the natural current of the *Tay* poſſibly can have in the neighbourhood of *Perth*; in ſhort, we make uſe of it in all our defences upon the *Calder*, and have never found it to fail. I know it will readily be urged, that the *Tay* being a larger river than the *Calder*, that what will do upon the one, may not do upon the other; it is true, that the *Tay* is a wider river, but it does not appear to be more rapid, that depending chiefly upon the fall, which in the *Calder* is above 8 feet per mile for above 20 miles together, that we are concerned with it, nor does it appear that the *Tay* in time of floods riſes to a greater height above its common ſurface. Hence I infer that the action of the *Calder* upon its banks is as great as that of the *Tay* upon its banks, becauſe the quantity of this action depends upon the height and rapidity of the water acting immediately againſt them, and not upon that which paſſes by at a diſtance from them, ſo that the width of the river is totally out of the queſtion.

In general I would adviſe my Lord Kinnoul to be as ſparing of theſe kinds of works as may be; for without a great deal of land be got or ſaved by a moderate quantity of work, though the method I have chalked out is the plaineſt, eaſieſt, moſt durable, and cheapeſt of any thing I know, where ſtone can be procured at a moderate expence, yet that land would come very dear that would require covering with rubble.

Perhaps it may be ſuggeſted that danger may ariſe from letting the great bulwark go to ruin; for when in that ſtate, if an inconvenience ſhould happen to ariſe, it would be much more expence to repair, than to keep it in repair. But this I apprehend to be quite otherwiſe; for a maſs of rubble thrown promiſcuouſly together, upon the ruins of the preſent bulwark, will be more laſting than the preſent one can be with its preſent materials and form, and can always be repaired by addition.

Upon the whole, it appears to me, that the greateſt damage done, or likely to be done, to my Lord Kinnoul's eſtate at this place, ariſes from currents of water topping the banks of the *Ammon*, and running over the ſurface with great rapidity, thereby taking away the earth, wear gullies, and leaving tracts of barren gravel in its room,

 which

which will be the moſt eaſily prevented by embanking the *Ammon* as before deſcribed, and ſtopping the mouth of any ſuch gullies as appear to lead the waters upon the land; yet notwithſtanding this will not prevent the back water from returning up the ſlades from below, and ſtanding upon the land to the ſame level as the *Tay* at the places of communication; however, the water there being in a manner ſtagnant, the ravage above mentioned will be prevented; but a total prevention of the floods from coming upon the lands can no otherwiſe be effected, but by embanking the whole round, both againſt the *Ammon* and the *Tay*, ſo as to be flood proof againſt the greateſt extremes, with a proper ſluice to let out the down-fall and ſoakage waters when the floods are over; and this, though I look upon it as a practicable work, yet the difference of rents upon the quantity of grounds concerned, does not ſeem to encourage an undertaking ſo conſiderable.

Having mentioned the expediency of banking againſt the *Ammon*, it may be underſtood I looked upon the *Ammon* waters to be the ſole cauſe of the overflowings already mentioned: but the caſe appears to me thus; when the *Tay* is flooded, it would revert upon the channel of the *Ammon* to the ſame level, though no current was to come down the *Ammon* at all; and were the banks of the *Ammon* lower than thoſe of the *Tay*, (as they really are about *Ammon Bridge*) the *Tay* would run up the *Ammon*, and firſt and moſt ſtrongly run over at the loweſt places, viz. near *Ammon Bridge*; but if at the ſame time that there is a flood in the *Tay*, there is one in the *Ammon* alſo, as muſt often happen to be the caſe, the current of the *Ammon* being ſtopped by the *Tay*, the *Ammon* muſt then be forced to riſe to a greater height, till it can over-ride the *Tay*'s water, and for that cauſe riſing to a greater height, will the more plentifully overflow its banks; but was the *Tay* low while the *Ammon* was in a flood, I don't apprehend much miſchief would enſue from the *Ammon* alone.

With reſpect to *Buſſey Mill*, I find that with the quantity of water iſſuing from the boot at the time I ſaw it, there is a power, when well applied and the machine rightly managed and uſed, of grinding a *Wincheſter* quarter of wheat per hour, and that ſuch an erection, if done here, would coſt from 4 to 500*l.*

Auſthorpe, 13th Dec. 1763. J. SMEATON.

RIVER

RIVER DEVON NAVIGATION.

Some Points relative to an intended Navigation upon the River *Devon*, ſtated by Lord CATHCART, and anſwered by JOHN SMEATON.

Sir,

IF I rightly underſtand you in our late converſation, your opinion upon the points ſtated to you was as follows.

My Lord,

THE points ſtated by your lordſhip contain the ſubſtance of what paſſed betwixt your lordſhip and me in converſation, therefore, to avoid repetition, ſhall note in the margin what I have occaſion to enlarge upon, or wherein your Lordſhip ſeems to have miſunderſtood me.

1ſt. That if the iſthmus of *Long Cars*, betwixt *Alloa* and *Cambus*, were cut with a canal, the ſides properly ſloped and faced with rough ſtone, (as you may more particularly explain in the margin) and the preſent channel of the *Forth* allowed to remain as it does, ſuch canal, the banks being of a height to contain the tide, would not endanger the adjacent lands by bringing more water that way than is intended., will have no occaſion for flood-gates, and will be an effectual improvement to the navigation, by avoiding the *Thraſk* ſhallows, and other impediments.

1ſt. In this particular I underſtood your Lordſhip that the *Thraſk* ſhallow is a flat ſhallow at low water, not of ſuch an height as to pen the water above it, but merely an impediment to navigation, through want of depth. This being the caſe, a canal cut through the iſthmus will have no other effect than here deſcribed, and the ſides of the canal being ſloped from the proportion of 2 to 1, to 1 to 1, as the ſoil may happen to be from a looſe earth or gravel to a firm clay, and being covered with rubble quarry ſtones (ſuppoſe one foot thick), ſo as to make a compleat cover, this will not only defend the bank from the action of the current, but of the waves occaſioned by the wind; but in caſe the ſhoal abovementioned makes a conſiderable pen, ſo as to determine the current much more ſtrongly through this new canal than through the courſe of the river, it will be neceſſary to defend

defend the *bottom also* with ſtones, to prevent the action of the water from deepening the ſame, and thereby ſapping the foundation of the ſtone facing, and in conſequence bringing down the banks and widening the canal. In caſe the pen ſhould be very conſiderable, it would be neceſſary to build a lock upon it; but the determination of this matter depends upon the length of the canal, and difference of level of the ſurface of the river at the head and tail thereof, taken at low water, when there is no freſh in the river, as alſo upon the quality of the ground forming the bottom.

2d. That if the river *Devon* was navigated by Sir JOHN ERSKINE, from the *Cobble Crook* to *Cambus*, by means of ſluices on *Tilli Body Bridge*, that navigation may be better effected by the canal and lock propoſed than it could have been by the ſluices, and the ground through which the canal paſſes, viz. from *Minoſtrie Lint Miln Dam* to *Tilli Body Bridge*, being clay and perfectly level.

2d. There is no doubt but that locks are preferable to ſimple ſluices.

3d. That from *Cobble Crook* to *Sauchie*, there being only two ſmall fords in the way, the navigation may be effected by one lock and dam at the loweſt ford, in caſe it ſhould not be found better to avoid the fords by cutting from deep water to deep water, and making a channel behind the fords; but that this expedient, which is the beſt, cannot take place if the preſent fords act as dams, and the new cuts

3d. I beg leave to add, that if a dam is built upon the ford, or the upper ford be ſuppoſed to act as a dam, a canal with a lock upon it, brought down ſo as to drop into the river below the lower ford, it will alſo equally anſwer the end if found moſt eaſily practicable. Alſo, if inſtead of joining the deeps by cutting a channal behind the fords, the fords themſelves be removed, or channels through them be made,

ſhould have the effect of letting down the river, and creating other fords in parts where the upper part of the navigation is intended to go.

made, this will alſo anſwer; but in this caſe, care muſt be taken to make the channels on ſuch ſide where the principal tendency of the water is to act in floods, otherwiſe they will be liable to be thereby filled up again.

4th. That you recommended carrying the navigation by locks out of the river at *Old Sauchie*, and raiſing it into a canal, upon the level of the river above *Tillicoutery Dam*, to be carried in the line and direction of Lord CATHCART's aqueduct, (till it falls under ground into the pipes where it croſſes the *Devon*) and there to be carried in an aqueduct bridge over the river, and continued to the dam, and from thence to the foot of the *Rack Miln Dam*, where there muſt be locks to ſurmount the ſaid dam, in caſe the navigation is carried on to *Vicar's Bridge*.

4th. This ſeems to be the method from what was deſcribed to me upon the plan; but as it is ſcarcely poſſible to form adequate notions without ocular inſpection, much muſt be left to the judgement of him who executes, in reſpect to the choice of the ground.

5th. That the level of the ſtretch from *Sauchie* to *Melloch* foot is proved by Lord CATHCART's aqueduct and the preſent ſtate of the *Devon*, which is already navigable betwixt *Tillicoutery Dam* and *Melloch*.

5th. Certainly, ſuppoſing the ſaid aqueduct to be carried upon a level.

6th. That the riſing of the river in times of flood, ſo as to overflow the aqueduct bridge, does not infer any danger, either to the bridge or adjacent lands.

6th. It muſt be ſuppoſed that the dimenſions of the water-ways, breadth and depth taken together, under the aqueduct bridge, muſt be ſuch as to vent the water as faſt as it comes in at extremes of floods, and alſo the ice in winter, otherwiſe great damage may enſue both to the works and adjacent lands, unleſs a certain length of the ſide walls of the bridge that ſuſtain

ſuſtain the canal are very ſtrongly capped with ſtone, and left lower than the reſt, for the water to flow over like a dam; but this expedient I would not recommend to be uſed, if it can be poſſibly avoided. N. B. I don't at preſent remember why the paſſage of the river cannot be obtained by raiſing a dam in the river below the intended place of croſſing.

7th. That, upon the whole, as thus repreſented to you, the navigation of the *Devon*, and the improvements of the navigation of that part of the *Forth*, between *Cambus* and *Alloa*, ſeems very practicable, and, from the nature of the levels, at a moderate expence, conſidering the length of the navigation.

7th. Agreed.

8th. That from your experience in navigation bills, and their conſequences when paſſed into acts, it is your fixed opinion, that the execution can neither be anſwered for, nor depended upon, in the hands of truſtees, and that the only ſafe and ſure way is for the proprietors of coal within reach of *Devon*, and Mr. ABERCROMBIE, to be the undertakers, or for Lord CATHCART to be the undertaker, with a proviſo in favour of the other coal proprietors and of Mr. ABERCROMBIE, in caſe they ſhall chuſe to recede, and naming a number of Commiſſioners to be

8th. This I have enlarged upon in my letter from *Newcaſtle*; I have only to add, that in this caſe the adventurers ſhould be fixed down to take a reaſonable toll for coals from the other coal owners, who may not in their preſent ſituation chuſe to be adventurors themſelves, otherwiſe the proprietors of the navigation may chuſe to loſe thoſe tolls altogether, to prevent the others from working their collieries, which would be a detriment to the public.

referred

referred to, and to judge betwixt the undertakers and other proprietors in all queſtions that may ariſe now or hereafter, with reſpect to damages, &c. in conſequence of this act, by which means the parties intereſted in the toll will attend to the execution; and as the toll never can be ſuffered by the undertakers to riſe to the price of land carriage, the difference, whatever it is, is ſo much ſaved, and therefore a benefit to the public.

9th. I forgot to aſk the dimenſions and ſize of the boats proper for the carriage of coal, and how deep water they will require.

9th. The ſize of the boats uſed for carrying coals is various in different places, and differ in ſize, ſhape, and draught of water, according to the convenience of the place; but I apprehend that ſuch boats as are principally uſed in the *Yorkſhire* rivers, will anſwer as well as any for ſuch a navigation, as propoſed by your Lordſhip, viz. 54 feet long, ſtem and ſtern poſt included, $13\frac{1}{2}$ feet wide, and 3 feet draught of water; thoſe will carry from 20 to 30 tons, according as they are more light or heavy built.

As alſo whether is a better method to land the coal from the canal on the pier, and load them from thence on board the ſhips, or to let the boats down into the river by locks, and put them on board directly from the lighters.

If the ſhips were always ready to be loaded, when the boats brought down coals, it would certainly be the moſt advantageous to lay the boats alongſide the ſhips; but when the ſhips are not ready, they muſt neceſſarily be landed upon ſome quay or wharf common to both,

Your certifying the above to be your opinion, or marking on the margin where I have miſunderſtood you, with ſome explanation for the ſatisfaction of the other perſons concerned in this bill, relative to the 1ſt, 6th, 7th, and 8th articles, with your

opinion upon the 9th, will very much oblige, Sir,

Your moſt obedient
humble ſervant,
CATHCART.

London, Feb. 11, 1765.

both, which I apprehend ſhould be covered like the coal ſtaiths at *Newcaſtle.* Whether the quantity that can be delivered alongſide the ſhips, in proportion to what cannot, together with the advantage of an open communication of the canal with the *Forth*, for the conveyance of other goods and merchandize, will make it worth while to make the neceſſary lock, is a matter of convenience that can only be determined upon the place, by thoſe well acquainted with the nature of the trade thereof.

The caſes ſtated, conſidered with my anſwers thereupon, contain the opinion upon theſe matters of,

My Lord,
Your Lordſhip's
moſt humble ſervant,
J. SMEATON.

Auſthorpe, 20th April, 1765.

QUERIES

QUERIES, &c. communicated by Lord CATHCART, relative to a navigation on the *Forth*, November 5, 1767.

BY the Report of Meſſrs. WATT and MORISON to the Board of Police, it appears,

That a navigation may be opened at a ſmall expence from the valuable woods, lime and ſlate quarries of *Aberfoil* to the bridges of *Aberfoil* upon the *Forth.*

That it may be continued from thence to *Cardroſs*, by a lock below the ford of *Cardroſs.*

That it may be continued from thence to *Frew* by a lock below the ford of *Frew.*

That from thence the river is navigable to a rocky ford called *Craig Anet*, betwixt the *Bade* and *Drip Coble*, which is two feet higher than *Craigforth* mill-dam, which laſt is three feet higher than the cruives of *Craigforth*, which are four feet above the neap tides, in the lower part of the *Forth.*

That a dam of three feet ſhould be added for the ſake of deepening the water, as far up as the *Frew*, which water ſo raiſed would be 12 feet above the neap tide.

That a canal near a mile in length, from a point above the *Bade*, acroſs level ground of a clay ſoil, with a lock of 12 feet fall, would compleat the navigation from *Aberfoil* to the tides-way at the new mill of *Craigforth.*

And that the navigation from thence downwards may be ſhortened about ſeven miles by four cuts, as expreſſed in the plan, below *Stirling Bridge.*

It appears by Mr. SMEATON's report to the proprietors of the *Devon* collieries,

That *Cambus*, with proper improvements, may be made a very convenient port for exporting ſea coal, and for accommodating ſhips in that trade.

That the river *Devon* may be rendered navigable from *Mellock* foot to *Menſtree Lint* mill-dam, which ſpace includes five collieries.

And that the navigation may be continued from *Menſtrie Lint* mill-dam, to the tideway in the *Forth* at *Cambus.*

Menſtrie mill-dam is 12 feet above the neap tides, therefore on a level with the water above the three-feet dam at *Craig Anet*, in the *Forth*, projected by Mr. WATT.

Suppose $2\frac{1}{2}$ feet added to the height of each dam, the water in the *Forth* above *Craig Anet*, and in the dam above the *Lint* mill-dam, will still be equal, and $14\frac{1}{2}$ feet higher than the neap tides.

The ground is clay, and very level from *Menstrie Lint* mill-dam to a point betwixt the bridge at *Stirling* and the new mill at *Craigforth*, where the banks on both sides are pretty high; and Mr. WATT's canal may be brought, upon very favourable ground, to a point opposite to it.

Suppose an aqueduct bridge of a proper dimension, erected across the *Forth*, betwixt these two points, (the distance being 300 feet) there will be dead water from *Frew* to the *Lint* mill-dam, by which the upper part of the *Forth* will have an easy, short, and open access to the *Devon* collieries, and also have an opportunity of dropping into the tides-way at *Cambus*, by locks of $14\frac{1}{2}$ feet fall, the advantage of which, considering how much lime-stone, slates, wood, &c. must come down, and how much coal must go up the *Forth*, including the consumption of the town of *Stirling*, and the inhabitants of those parts of the country that come through *Dumblain*; and that the lock at *Craigforth* new mill, and a great length of navigation, and the loss of time in waiting for the tide, will be saved, is extreamly obvious.

The only circumstance of doubt is the practicability and expence of the aqueduct bridge, the length being 300 feet, and the bottom of the river clay, and far above rock; if it is executed in stone, the number of piers which it will require, as the level will admit of so small a rise for the arches, and the foundation which must be piled, it is apprehended must render the expence enormous. If it is executed in wood, upon the plan of *Julius Cæsar's* bridge, which is well-adapted to resist ice, or other floating bodies, or upon any better more modern construction, it is apprehended it would come much cheaper, would stand against the force of the stream, and of the ice in winter, and would not be affected by the land floods, which cannot rise to the sole of the aqueduct, but must be liable to the expence of repairs to which a stone bridge would not be subject.

Mr. SMEATON, who is acquainted with the nature of the rivers and country adjacent in question, and skilled in every expedient that may facilitate the junction of the two level canals, by an aqueduct, is desired to say,

1st. Which of the two plans, the aqueduct bridge and canal to join it to the *Devon* at the *Lint* mill-dam, or the lock at *Craigforth* new mill, seems, upon the face of them, the most eligible for the inhabitants of the upper part of the *Forth*?

2d. If

2d. If the aqueduct plan seems the most eligible, what *data* will be necessary to furnish Mr. SMEATON with, to enable him, at his leisure, to make out a design for the bridge.

3d. Does Mr. SMEATON think that the boats recommended for the *Devon*, drawing three feet water, of $13\frac{1}{2}$ feet width, and 56 feet long, will answer all the purposes of the *Forth* boats, or would it not be proper to allow for a foot more draught of water, in order that their slates, &c. may be carried coastways, and that the locks and canals be for that purpose proportionably deepened?

4thly. Suppose the aqueduct bridge rejected, and the lock at *Craigforth Mill* adopted, will it not be expedient to make the four cuts in the *Forth*, as marked in the plan; and if-any, but not all, which of them?

5th. The ditches from *Tillibodie Bridge* to *Manner Pow* are from 8 to 10 feet deep, and about 12 feet wide, and are on a level with the *Devon*, at *Tillibodie Bridge*, and with Sir JOHN ERSKINE's canal at *Cambus*, would it not be right to build a lock at *Manner Pow*, and to enlarge these ditches, that *Upper Forth* boats might get, by that tract, to the collieries, whereby upwards of 6 miles navigation would be saved?

ANSWER to five Queries concerning the improvement of the Navigation of the River *Forth* from the River *Devon* upwards, communicated by the Right Honourable the Earl of CATHCART, in a Letter of November 11th, 1767, to JOHN SMEATON.

1st. IF the communication of the *Devon* collieries with the upper *Forth* was the sole object in view, then the long canal, from above *Stirling* to the *Lint Mill Dam*, upon the *Devon*, seems very well adapted for that purpose, and in that case would merit serious consideration, how far the aqueduct bridge, over the *Forth* (which indeed seems the only difficulty) might not be (under the specified circumstance of elevation) an executable scheme; but if the expence and difficulties of executing such a bridge there, as well as the expences of land, cutting bridges, and other contingencies attending the proposed canal

canal be confidered, and that at laft it will not fave above 5 miles * of diftance, though none of the loops below *Stirling* are fuppofed to be cut; if, on the other hand, the advantages arifing from a free and open navigation to all parts of the *Forth* below, for all kinds of traffick, be put in the other fcale, I cannot hefitate to fay, the advantages being confidered with the expence, and probability of trade, that it appears to me, on my prefent view of the propofition, more eligible to lock down into the *Forth*, near *Craigforth* new mill, and below that to keep the river.

2d. This is anfwered by the firft.

3d. If the veffels were made of greater draught of water than 3 feet, and wider than 13 feet 6 inches, they would undoubtedly be more fafe in navigating the broad part of the *Forth*, and coafting, and could venture, and keep out in worfe weather; but fuch veffels, as defcribed for the *Devon*, not only go in the narrow rivers in *Yorkfhire*, &c. and down to *Hull*, but even go out to fea, and crofs the *Lincolnfhire* wafhes to *Spalding* for corn, to be carried in the fame veffel to *Leeds*, *Wakefield*, and *Halifax*; but as it is obvious that if the bulk of the veffel is increafed, it will occafion greater expences in executing the locks, cuts, canals, &c. it may therefore be worth while to confider, with *the degree of trade that is probable*, whether it may not be eligible to fave a capital that muft thereby be expended by changing: for though the veffels above-mentioned can, and do go as before fet forth, yet the bulk of trade is carried on by changing veffels at *Armine*, that is as foon as the river is capable of receiving floops of 50 and 60 tons.

4th. The moft important object in making artificial navigations, is to avoid dead ftoppages by want of water, &c. In many principal navigations in England, veffels are frequently ftopped in dry feafons for one, two and three days at a time, fometimes for a week together. Now, if they had a certainty of going at a particular time of tide, twice in 24 hours, they could fuit their times accordingly, and would be content to go feveral miles about, if they had a certain paffage, rather than lie ftill fo long together; for this reafon, cuts are feldom made merely and fimply for fhortening diftances; and though in the diftrict under confideration the river is remarkably crooked, yet, as the reft of it, both above and below, is but little better, it may deferve a ferious confideration whether it is worth while to make any of the cuts propofed below *Stirling*; for as, according to the plan I have, the difference of diftance is but about 5 miles, with the cuts and without them, the Engineers would therefore do well to confider, from actual admea-

* The diftance up the *Devon* being taken into the account.

furements

furements of the refpective lengths, and levels taken, how deep, how wide at bottom and top, each cut will be required, in order that they may be materially more paffable than the prefent fords; and to effect that, how deep they will be required to be dug below low water, what land muft be cut and covered; thefe things being afcertained, and proper eftimates made from the price and quantity of excavation, the price and quantity of land, the charge of pumping water while the digging is going on under level, and the damages that may be done by the river's breaking in while the works are going on in that fituation, alfo the charge of making dams to turn the water from the cuts, or if none, the time loft in getting the tracking horfes acrofs the old loops; I fay all thefe things confidered, and eftimates formed from particulars, will foon direct you, whether from the probable quantity of trade, the expence of any, all, or fome of thefe cuts, will be balanced by the time in the paffage refpectively faved. The two upper ones feem the moft advantageous, the reft in order as they are lower; but it will be right to have a power in the Act to make any of thefe cuts; that after the neceffary canals, locks, &c. are made, if it fhall appear from the quantity of trade, and the goodnefs of the funds, that the thing is eligible, there ought to be a power of doing it without a frefh application.

5th. The expediency of this ftep confifts in the facility in doing it, becaufe the advantage will wholly confift in the trade with the *Devon*; for it will not be worth while for a veffel at the mouth of the *Devon*, and going up the *Forth*, to make ufe of this paffage, becaufe, in going round the great loop, fhe will be thrown about only $1\frac{1}{2}$ mile more than the artificial paffage, in which latter fhe would have to pafs two locks.

It is to be obferved, that by a double entry into *Devon* the leakage will be double; and if made ufe of as a paffage up and down the *Forth*, each veffel will expend two lockfulls, except in cafes of meetings.

Aufthorpe, November 21, 1767. J. SMEATON.

Lord CATHCART's Queries relative to the River *Devon*.

MR. SMEATON to confider the *Cambus*, and the river below the *Cambus*, and to give his opinion, whether the *Cambus* can be made a proper port of exportation for great coals, and if it can, by what means, and at what expence.

Objections.

Objections. Want of depth of water, expence of making a new port, loss of time to ship-masters to come so much further; danger from ice in winter.

If either impracticable, or too expensive, Mr. SMEATON will consider whether the coals cannot be carried in boats down the *Devon* and *Forth* to *Alloa*, and there shipped for exportation.

Objections. Coals carried down to *Alloa* by water cannot be folded there without great expence, but must be loaded from the lighters, which ship-masters object to, for reasons perhaps frivolous, but will best be collected from themselves, and judged of by Mr. SMEATON.

If coals brought down the *Devon* can be exported either from the port of *Alloa*, or of *Cambus*, Mr. SMEATON will then consider the best method of rendering the *Devon* navigable, from *Mellock* foot to the *Forth*, either by a canal, or in the bed of the river, or partly by one, partly by the other, calculating the expence of the whole, and specifying the dimensions of boats, what they are to carry, and how to be drawn.

The size and dimension of boats will depend upon the use intended; if they are not to be let into the *Forth*, they may be very long, very narrow, and very shallow, which will reduce the expence of the canal. If intended to go down to *Alloa*, or up the *Forth*, they will not admit of the same construction.

N. B. The possibility of going up the *Forth* by water from the collieries would be a great conveniency, because were the navigation opened above *Stirling Bridge* by locks at *Craigforth*, *Frew*, and *Cardross*, all the country on each side the *Forth* might, as well as the town of *Stirling*, be supplied by water-borne coals from the *Devon* collieries.

If Mr. SMEATON finds any species of navigation practicable and adviseable, he will favour the coal masters with his ideas of the proper Act of Parliament to be petitioned for; and of the places, proportion, and manner of collecting tolls, and manner of shipping the coals either from boats or quays; and if he will undertake, or recommend an undertaker for the whole, or the locks only, and on what terms.

To this may be added a remark of Messrs. MACKELL and WATT lately made; that is, that a canal may be carried upon a dead level the whole way from *Tillicoutery* to a point opposite to the schoolmaster's house at *Alloa*, following the foot of the rising grounds

the whole way, that it will be about 30 feet higher than the ſea, and may either be carried betwixt banks acroſs the flat grounds, which is not far, to the ſhore, otherwiſe the flat ground may be cut to bring the *Forth* up to the low grounds.

This would ſave locks and waſte of water as far as *Tillicoutery*, and might be joined by a canal from *Mellock Foot*, the level of which would be a very little higher, and might require a lock.

Levels.	Feet.	Inches.
From *Forth* to *Sauchie*, - - -	18	10
From *Sauchie* to *Mellock*, - - -	19	6
From *Mellock* to *Vicar's Bridge*, - -	39	6
	77	10

The REPORT of JOHN SMEATON, Engineer, concerning the practicability and expence of making navigable the River *Devon*, in the county of *Clackmannan*, from *Melloch Foot* to the River *Forth*.

THE river *Devon* falls into the river *Forth* about 2½ miles above, or to the weſt of *Alloa*, but according to the turns of the navigation, up *Forth*, about 3½ miles. There are ſeveral valuable collieries upon the ſlope of the hills that decline towards the river *Devon*, the coals of which are now carried to *Alloa* over land, in order to be put there on board veſſels capable of carrying them to all parts where wanted. The more eaſy carriage therefore of thoſe coals; from the collieries to the ſhipping is, as I apprehend, the principal object of the preſent propoſed navigation.

At the mouth of the *Devon* the extreme ſpring tides are ſaid to riſe 20 feet perpendicular, and at ſuch tides the water flows one foot higher than the top of *Cambus Quay*, which is an old quay, at which formerly coals were ſhipped, about a furlong within the mouth of the *Devon*. The common neap tides are ſaid to riſe within five feet of the top of the ſaid quay, and that then there is 12 feet water in the river *Devon* oppoſite the ſaid quay. When I was there, the morning of the 20th of November, 1766, being the fourth day after the full moon, it appeared that the mark left by the laſt tide was as high as any that had been that ſpring, and what might be called an ordinary ſpring tide: this I found had been within 1 foot of the top of the ſaid quay; and conſequently, being 4 feet higher than the ordinary neap tide mark, made 16 feet water in the river oppoſite the quay. At the time I was there it was almoſt low water in the *Forth*, and then the current of the *Devon* run with a conſiderable declivity towards the *Forth*, having a fall of not leſs than 2 feet.

The declivity of the bottom of the river from *Cambus Quay* to the *Forth* appears pretty regular; the bottom oppoſite to and above the quay ſeems to be mud, intermixed with large tumbling ſtones; theſe ſtones being removed, the mud would waſh away, ſo that I look upon it as very practicable to make 2 feet more water at *Cambus Quay* than at preſent, that is, to make 14 feet at ordinary neaps, and 18 feet at common ſpring tides.

If more water than the above ſhould be requiſite, I ſhould look upon it as more eligible to dig out a new channel and harbour from the *Forth*, which may be done on the weſt

west side of the *Devon*, the ground there being low and flat, and gently rising from low water mark; this work may, therefore, be done at a moderate expence in proportion to such a work, but yet must, in digging, walling, &c. amount to a considerable sum, more than would be necessary to rebuild and enlarge the old quay and deepen the river, as aforesaid.

To the safety of the place there seems to me no material objection; for as to ice in winter, it cannot do much harm, as it must be much broken in passing the bridges and dams before it gets to the *Cambus*. It is no peculiarity of the river *Devon*, and is the case, more or less, with every sea port which has the advantage of being scoured by a fresh water river, which is in itself very desireable.

In going up the *Forth* from *Alloa* to the *Cambus*, the navigable channel of the river makes one large half moon, but as it is in general sufficiently spacious for vessels to turn, this case also differs little from what is common in other tide rivers; it will undoubtedly be some hindrance to vessels going $3\frac{1}{2}$ miles further up, but as this can hardly ever be attended with more than one tide loss of time, and often without the loss of a tide, it may as well be said that the coals ought be carried down to *Kincardine Road*, to prevent the possibility of the loss of a tide in going to *Alloa*. The principal impediment in getting betwixt *Alloa* and *Cambus*, for vessels of burthen, is occasioned by a shoal called the *Frask*; and this arises not so much from want of depth of water, as from the narrowness of the channel; for in sounding the river at low water the day above specified, we sounded in the channel over the *Frask* no less than 5 feet, which, though the shallowest place between *Alloa* and the *Cambus*, seems yet a very sufficient passage, at all proper times of tide, for vessels bound to an harbour, where they could lay dry at low water the same tide.

This shoal seems to consist of a ledge of stones which lays almost across the river from S. W. to N. E. confining the channel close in with the point, which is an unnatural situation for the channel, but arises from the greater softness of the ground in that part where the channel is. As this shoal is short, according to the direction of the channel, it seems very practicable to remove the stones, so as to increase the same in width. There is at present a sufficiency of width, when proper beacons are set, for the passage of vessels right upon and down, but not of those turning to windward.

This shoal may also be avoided by cutting through the neck of land; but if the great depth that such cut will be required, (the ground seeming there 18 or 20 feet

higher

higher than low water) the depth to which it must be carried below low water, and the great width that it must have in the bottom, to make it a more eligible passage than by the *Frask*, be considered, I believe it will appear that the canal may be extended to *Alloa* for almost as little, if not less expence. It perhaps may be expected that if the cut is made narrow, and down to low water, that in time it will wear itself wider and deeper, and so indeed it may, but whether this will happen in the compass of seven years or twenty, or whether it will ever happen, so as to be (as already said) a more eligible passage than the *Frask*, I think is out of the power of any man to say with certainty; for it is to be observed, that till it becomes much wider than the *Frask* and equally deep, it will be more difficult to turn to windward through it on account of its greater length.

As the natural declivity of the river from head to tail of this supposed cut is very little, unless a dam was put across the main river to force the current through the cut with some considerable velocity, the water could not in its natural state be expected to operate very speedily; and as the width of the river through its several channels in this place is very considerable, such dam would be very expensive, would obstruct the navigation while the new channel was wearing larger, and by depositing of the matter and diverting the present channel, there is no saying but that after all a shoal might be formed in some place where now there is none, as troublesome as that we would mean to avoid; for these reasons I cannot, in my present view of the matter, recommend this division of the river from its present channel.

With respect to the dimensions of the canals, cut out from the course of the river *Devon*, they depend upon the kind and sort of vessels to be employed, and the sort of vessels will again be determined by the uses to which they are to be applied.

If the vessels are to be employed merely in bringing down coals from the collieries to the quay, where the ships load without going into the *Forth*, vessels long, narrow, and shallow, may be used with advantage, but if intended to go up and down the *Forth*, they will require a different construction.

It seems to me, that if the navigation be limited to the canal only, without going into the *Forth*, it will be attended with many inconveniencies, but that it will be of more general use, if capable of containing vessels capable of going up and down the *Forth*, as well as of navigating the canal; for by this means vessels may be loaded at the *Cambus* Quay, or at *Alloa*, as may be most suitable to the sea vessels to be loaded,

or

or they may be carried up the *Forth* to *Stirling*, and up to *Gartmore*, in case the navigation above *Stirling* is compleated, which if confined to the winding course of the *Forth* may be done at a very moderate expence, as I have formerly shewn in my report on the proposed canal from *Forth* to *Clyde*.

The very extensive trade up the river *Aire* and *Calder* in *Yorkshire*, which passes under *Ferry Bridge*, and of which coals is the principal article, is carried on in vessels of 56 feet long, stem and stern, 13 feet 6 inches wide, and drawing 3 feet water at a medium; in very dry times in summer they load 6 inches less, and in winter 6 inches more. These vessels at 3 feet draught of water carry, by reputation, from 20 to 25 tons, but of neat dead weight 28 tons; they are generally drawn by one horse, and make way nearly two miles an hour, stoppage at the locks included; though sometimes, for the sake of expedition, and when there are freshes in the river, and the vessels going against stream, they make use of two.

These vessels not only navigate in the narrow rivers, but go round into the *Trent* to *Gainsborough* and *Newark*, and frequently down the *Humber* to *Hull*. This sort of vessel, I apprehend, by the same rule, would not only go down to *Alloa*, and deliver their cargoes there on board ships, but would occasionally go into the *Carron*, and through the great canal, in case the same should take effect.

By this means, if a large ship meets with contrary winds, or comes in at such a time as to expect being neaped at the *Cambus*, she may be loaded at *Alloa* from the boats, in the same manner as all the ships at *Newcastle* and *Sunderland* are loaded from the keels there, which carry 21 tons each; on the other hand, when there are no ships that want loading at *Alloa*, or they happen to be brought down faster, then they are shipped at the *Cambus*, or sent away in the same bottoms to other places up or down the *Forth*, they then will be deposited in the coal-yard at *Cambus*, ready for the vessels that come up thither for a loading.

The dimensions of the *Calder* cuts for the vessels above described were, 16 feet bottom, the sides sloped 5 feet for 3 feet of perpendicular, and carrying 3½ feet of water; now in carrying canals upon a dead level on the decline of hills, the ground is seldom so free from irregularities, but that it requires extra cutting in some places, and extra banking in others, which, as it would be impossible to determine exactly before the execution, as every variation, though but for a few yards, would vary the dimensions, must be allowed for according to the judgment of the artist; to make allowance therefore for the

common

common inequalities of ground in the present case, I compute upon a cut of 6 feet deep, that is, supposing the water $2\frac{1}{2}$ feet within soil; not that I expect it to be so in the general; but as in many places the extra cutting will be considerably more, and the deficiencies remain to be made good by so much labour, I make that supposition in order to come at the mean value.

Upon these general dimensions I have computed the expence, upon a supposition of an entire canal, except where it is proposed to come into the river, for the sake of crossing the same, to get the eligible ground, which amounts to the sum of 9357 *l.*

2d. Supposing the river to be made use of in the general from *Tillibodie Bridge* to *Sauchie* new engine, with short cuts to take off loops and place the locks, in this case, though far less apparent work, yet as the disadvantage of placing the locks, as well as of constructing them, and laying their foundation below the level of the river, as it will require a lock more, a greater price for each lock, a greater depth of cut, and, on account of greater depth, as well as drainage of water, a greater price per yard of digging; I say, all those being allowed and computed, as in my judgment they ought to be according to the following estimate thereof, this will make the whole stretch from *Tillibodie Bridge* to the elbow of the river above *Sauchie* old engine, near *Tillicoutery Burnfoot*, to amount to 4793 *l.* whereas if done by canal, according to the first supposition, it will cost 5183 *l.* the difference being 390 *l.* in favour of the river navigation; but if it be considered, that following the river increases the length near $1\frac{1}{2}$ mile in $6\frac{1}{2}$ miles, and that the works themselves will be perpetually in greater hazard from floods, and need more repair, this difference does not appear to be worth the saving.

As I observed the ground very capable thereof, I have computed the value of two miles of canal, which I suppose, if turned southwards a little below *Menstrie Bridge*, will carry it to *Alloa*: this is done upon a supposition of 40 *l.* an acre for the land, which I apprehend to be very valuable in that district, the rest of the dimensions and prices as per first supposition; this will cost the sum of 2408 *l.* This supposes a lock into *Forth*, but being nearly the same as that at *Cambus*, the only addition is in the canal.

Respecting the prices of land, I would be understood once for all, that I don't in these estimates by any means propose to fix a value upon it, as being an affair quite out of my province; but when different schemes are to be compared together, some value must be affixed to each of the component parts, in order to bring them to a comparison; for the cuts upon the valley of the *Devon* I suppose 20 *l.* per acre average price, though

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I am very ſenſible that ſome of the grounds through which the cuts will paſs, are more than ten times the value that others are: but as I apprehend the whole of the ſuppoſed cut from near *Menſtrie Bridge* to *Alloa*, will paſs through grounds as valuable as the beſt in the *Devon* valley, the compariſon would in no reſpect hold, unleſs an addition was made to thoſe ſuppoſed for the *Alloa* cut.

I now come to the article of water, and for this purpoſe particularly obſerved the new mill at *Tillibodie*, which is ſituated upon the river *Devon*, and enjoys the whole ſtream thereof; its water is penned by the ſame dam, from whence the cut is propoſed to be taken to *Cambus Quay*. This mill, when going at its common rate, requires the ſluice to be drawn up 11 inches upon a breadth of 3 feet, there being then a depth of water upon the ſole of 25 inches.

Having hence computed the quantity of water expended when the mill was going at this rate, it comes out to be 1180 cube feet per minute. A lock required to carry veſſels of the ſize above ſpecified, will require to be 62 feet long, and 14 feet wide, whoſe area upon each foot in depth will be 868 feet; and ſuppoſing a lock to be of 6 feet pen, this will require 5206 cube feet to fill it, and the paſſage of each boat will require this quantity, unleſs two boats ſhould meet together at a lock, one going up, and the other down, they then will both paſs with one lock-full; but as this does not always happen, I generally reckon upon a lock-full to each boat, the ſavings of water upon the aforeſaid circumſtance going in aid of the loſs of water at the locks by leakage. Now the contents of a lock 5206 cube feet, being divided by 1180 cube feet expended at *Tillibodie Mill* per minute, gives $4\frac{4}{10}$ minutes for the time in which the ſaid mill expends a lock-full of water of 6 feet high.

Again, if we ſuppoſe 10 boats to paſs in a day, that is, 5 up and 5 down, we may very well ſuppoſe that out of theſe 2 may meet at or within ſight of the lock; and if ſo, a lock-full of water will be ſaved, which I eſteem equal to the daily leakage of a well-made lock; but however, to make an ample allowance for loſs of water, not only by leakage, but by evaporation and accidents in dry weather, I will further allow 4 locks-full per day; the total expenditure will then be 14 locks-full, which will be equivalent to 61.6 minutes, or $1^h\ 1'\ 42''$; and this will be the time that *Tillbodie* new mill ſingly, and the two mills at the *Cambus* conjointly, will loſe in 24 hours in the drieſt ſeaſon; for at all other times, when the water runs waſte over the dams, the navigation will not leſſen the time of the mills working.

By

By information of the miller, there is in ſummer ſcarcely half the above quantity of water in dry ſeaſons, that is, they can ſcarcely go at that rate above 12 hours in 24; hence the navigation, circumſtanced as beforementioned, will conſume about $\frac{1}{11}$ part of the water that now goes to the mills in dry ſeaſons; or, dividing the whole quantity into 11 parts, the mills will get 10 and the navigation 1; but, upon my view, it appeared, that *Tillibodie* new dam was conſiderably leaky, inſomuch that it is probable that in dry times as much water goes through the dam as goes to the mill; this will be the caſe if the leakage is only half the mill ſtream when working; for one being conſtant, and the going but for half time, they will be equivalent to each other; but, as it may be neceſſary to make ſome alterations in the dam of *Tillibodie* new mill, if this is rendered water-tight at the expence of the navigation, this mill will be a gainer and not a loſer by the navigation. The *Cambus* mills, however, which are ſituated upon the ſame river, and take their water from the new mill of *Tillibodie*, and receive alſo the leakage from that dam, will not be compenſated by that alteration; but as both the mills at *Cambus* work from one head of water, the loſs to them both will be no greater than was eſtimated for *Tillibodie* mill ſingly; but the loſs to neither of thoſe ſets of mills will take place, as to the lockage, except for ſuch veſſels as go down into the *Firth*; for all ſuch veſſels as deliver their cargo into the yard at the *Cambus* for ſhipping, which may be expected to be far the greateſt part, will expend no more water from *Tillibodie* or *Cambus* mills.

It is true that, according to the different ſtates of the tide, a perpendicular height might be wanted greater than ſix feet; but as it will be often leſs, I ſuppoſe the one may nearly balance the other.

It would render the affair of the mills intirely free from compenſations if a ſtream could be turned into the *Devon*, that now goes into ſome other river, equivalent to what will ſupply the navigation, which, from my view in paſſing through the country near the head of the *Devon*, does not ſeem difficult to do.

However, upon the whole, it appears, that even in an extended view, the quantity of water that will be uſed by the navigation will bear but a ſmall proportion to the currency of the river *Devon*, even in the drieſt ſeaſons; and as a ground-work for a compenſation, in caſe an equivalent quantity of water cannot be brought into the *Devon*, it appears that for every 5206 cube feet of water that is drawn out of each head, at ſuch times when the reſpective mills can uſe the whole, a ſum equal in value to $4\frac{4}{10}$ minutes work

work of ſuch reſpective mills will be payable to the tenant or occupier of ſuch mill or mills, he continuing to pay the ſame rent as before.

Now, excluſive of *Sauchie* engine, which will be proportionably affected with the reſt, there are only three heads of water that will be affected, viz. the *Cambus* mills, which are corn-mills; *Tillibodie* new mill, which is alſo a corn-mill; and the mill above *Tillibodie Bridge*, which is a lint-mill; which, in proportion to the value of its time, will be affected in much about the ſame manner.

I make no account of ſoakage, becauſe this, after the canals are ſeaſoned, will be very trifling, and the greateſt part will return into the river above the principal mills.

Auſthorpe, September 14, 1767. J. SMEATON.

P. S. In regard to the ſcheme that has occurred to Meſſrs. MACKELL and WATT, ſince I was upon the place, of carrying a canal upon a dead level from *Tillicoutery* to a point oppoſite the ſchoolmaſter's houſe at *Alloa*, following the foot of the riſing grounds the whole way, and which will be about 30 feet higher than the ſea, propoſing to continue the ſame from thence between banks acroſs the flat ground to the waterſide (which is not far), or making a cut through the flat grounds to the dead level termination of the canal, which plan would ſave locks and waſte of water, I can only ſay, that, from my view of the country, I believe ſuch a project practicable; but, as I have neither plans nor ſections of the courſe that it would take, I am in no capacity to judge of the expence.

It is obvious that this canal would be defective in not ſuffering the veſſels to paſs into the *Forth*; and that either the banking acroſs the valley, which would be a conſiderable height, or digging acroſs it, which would be a conſiderable depth, would be a conſiderable article of expence; and that in any view of the affair, if a communication with the *Forth* is diſpenſed with, a conſiderable ſaving may be made, but I apprehend not above 1-3d, between carrying veſſels to navigate the *Forth*, as above ſpecified, and thoſe the moſt curtailed that can any ways anſwer in point of quantity.

J. S.

ESTIMATE for making a Navigation through the valley of the river *Devon* from the *Cambus* to *Mellock Glen Foot*, ſuppoſed chiefly by a canal.

	£.	s.	d.
To widening and deepening the old cut from the *Cambus* into *Tillibodie* new mill-dam, which, from the depth of the ground, I eſtimate as a new cut, the width at bottom being 16 feet, mean width at top 36 feet, mean depth 6 feet, at 3*d.* per yard, will come to 47*l.* 13*s.* 4*d.* per furlong, the length being 4½ furlongs, - - - - - -	214	10	0
To 1 lock from the cut into the tideſway, - - - - - -	600	0	0
To 6,14 acres of land, if purchaſed at 20*l.* per acre, - - - - - -	122	16	0
To 1 cart-bridge for communicating with the land cut, - - - -	40	0	0
To repairing *Tillibodie* new mill-dam, ſo as to render the ſame more nearly water-tight,	200	0	0
To extra cutting for paſſing-places, &c. - - - - - -	27	0	0
To extra land for ditto, - - - - - -	15	0	0
From Cambus Quay to *Tillibodie Bridge*, - - - - - -	1219	6	0
To clearing up and deepening the river from *Tillibodie Dam*, through the bridge, to the tail of the next cut, - - - - - - - -	50	0	0
To cutting 3 miles 1 furlong of entire cut, of the dimenſions above ſpecified, from *Tillibodie Bridge* to *Sauchie* new engine, that is, 25 furlongs, at 47*l.* 13*s.* 4*d.* - -	1191	13	0
To 34,1 acre of land, if purchaſed at 20*l.* at a medium, - - -	682	0	0
To a road-bridge over the cut, anſwerable to *Menſtrie Bridge*, with a ſtone arch, -	80	0	0
To three cart-bridges to preſerve the roads and communications between lands, from the above to *Sauchie* new engine, - - - - - - -	120	0	0
To extra cutting for paſſing-places, &c. - - - - - -	149	0	0
To extra land for ditto, - - - - - - -	85	0	0
To digging a cut from *Sauchie* new engine to the elbow of the river near *Tillicoutery Burn Foot*, being in length 1 mile or 8 furlongs, at 47*l.* 13*s.* 4*d.* per furlong, - - -	381	7	0
To 10,91 acres of land, at 20*l.* - - - - - - -	218	4	0
To 2 cart-bridges over this cut, - - - - - - - -	80	0	0
To 3 locks upon this diſtrict, at 500*l.* each, - - - -	1500	0	0
To extra cutting for paſſing-places, &c. - - - - - -	48	0	0
To extra land for ditto, - - - - - -	27	0	0
To extra expence in cutting through the riſing ground at the *Coble Crook*, - -	100	0	0
From *Tillibodie Bridge* to the head of *Sauchie Cut*, - - - - -	4712	4	0

To

	£.	s.	d.
To raising a dam to pen about 7 feet water in the elbow of the river next above *Sauchie* old engine, near the foot of *Tillicoutery Burn*, - - - - - -	500	0	0
To embanking the flat ground adjacent to the river *Devon*, on the north side from the said dam upwards, so as to be flood-proof, supposing it, at a medium, to be ¼ of a mile in length, 6 feet height, 6 feet top, and 24 feet base, this will contain 4400 yards, ramming and sodding or turfing included, at 4*d*. - - - - -	73	7	0
To 1 ½ acres of land, that will be cut and covered by this work, . - -	30	0	0
To extra expence in securing the land near the foot of the dam, and in guarding the same from the effects of *Tillicoutery Burn*, suppose - - - - - - -	100	0	0
Expence of continuing the navigation half a mile up the river *Devon*, from the head of the *Sauchie Cut* to the tail of the cut near the bridge of *Tillicoutery*, - - -	703	7	0
To widening or making a new cut past the bridge of *Tillicoutery*, from the dam into the river below the tunnel wherein the engine water crosses the same, being in length 2 furlongs, at 47*l*. 13*s*. 4*d*. per furlong, - - - - - -	95	7	0
The land cut and covered will contain 2,73 acres, which, at 20*l*. an acre, comes to -	54	12	0
To a lock upon the said cut, - - - - - -	500	0	0
To a road-bridge over the said cut, answerable to *Tillicoutery Bridge*, - -	80	0	0
The cut, &c. to pass by *Tillicoutery Bridge* into *Tillicoutery Dam*, - - -	729	19	0
To cutting across the flat grounds from the first elbow of the river above *Tillicoutery Dam* to *Mellock Glen Foot*, being in length 5 ½ furlongs, at 47*l*. 13*s*. 4*d*. - - -	262	3	0
The land cut and covered 7,5 acres, at 20*l*. per acre, - - - -	150	0	0
To a lock upon the said canal, - - - - - -	500	0	0
Two cart-bridges for preserving communications, - - - -	80	0	0
To extra cutting for passing-places, &c. - - - - - -	33	0	0
To extra land for ditto, - - - - - - -	19	0	0
To carrying the navigation from *Tillicoutery Dam* to *Mellock Glen Foot*, - -	1044	3	0

SUMMARY of the Estimate for making a Navigation through the valley of the river *Devon*, from the *Cambus* to *Mellock Foot*, supposed chiefly by canals.

	£.	s.	d.
From *Cambus Quay* to *Tillibodie Bridge*, - - - - - -	1219	6	0
From *Tillibodie Bridge* to the head of *Sauchie Cut*, at the elbow of the river above the old engine at *Sauchie*, and near *Tillicoutery Burn Foot*, - - - -	4712	4	0
From thence, through the river, to the foot of the cut that passes *Tillicoutery Bridge*, -	703	7	0
The cut to pass by *Tillicoutery Bridge* into *Tillicoutery Dam*, - - -	729	19	0
From *Tillicoutery Dam* to *Mellock Glen Foot*, - - - - - - -	1044	3	0
Carried over	8408	19	0

	£.	s.	d.
Brought over -	8408	19	0
To 6½ miles of towing-path, which, with towing-bridges, gates, stiles, back drains, &c. is supposed to cost, 15 *l.* per mile, - - - - - -	97	10	0
	8506	9	0
Add 10 per cent. for unforeseen accidents and expences not included in the foregoing estimate,	850	12	0
	9357	1	

ESTIMATE to shew the difference between keeping the river as much as possible from *Tillibodie Dam* to *Sauchie* new engine, and the entire canal before proposed.

To clearing up and deepening *Tillibodie Dam*, through *Tillibodie Bridge*, to the tail of the cut, as before, - - - - - - - - -	50	0	0
To cutting from *Tillibodie Bridge* into the *Lint Mill Dam*, being in length 4 furlongs, and which passing through deeper grounds than if carried upon a dead level, may be supposed 7 feet mean depth, which, with bottom and slopes as before, will contain 18164 yards, and which being deeper, and partly under level of the river, so as to require artificial drainage, I reckon at 4 *d.* per yard, - - - - - -	319	8	0
The ground cut and covered will be, at a medium, 100 feet wide, and therefore 4 furlongs will contain 6,06 acres, which, at 20l. an acre, comes to - - -	121	4	0
A lock upon ditto requiring drainage, and to be built higher than if upon a dead cut, -	550	0	0
A cart-bridge over the cut for communication, - - - - -	40	0	0
The work to pass the *Lint Mill* above *Tillibodie Bridge*, - - - -	1080	12	0
To making a cut at the letter A, of 1 furlong of dimensions, as the former, will contain 4791 yards, at 4 *d.* - - - - - - -	79	17	0
The cut and cover will contain 1,51 acres, which, at 20 *l.* comes to - - -	30	2	0
A lock upon the cut as before, - - - - - - -	550	0	0
A cart-bridge over the lock for communication to the island, - - -	15	0	0
A dam to pen the water, - - - - - -	300	0	0
Cut, &c. at the letter A, - - - - - - -	974	19	0
To making a similar work at B, which will carry the navigation to *Sauchie* new engine, -	974	19	0
To 1 mile of cut, from *Sauchie* new engine to the elbow of the river near *Tillicoutery Burn Foot*, as per former estimate, - - - - - -	381	7	0
The land for ditto, as before, - - - - - -	218	4	0
To two cart-bridges, as before, - - - - - -	80	0	0
To a lock from the cut into the river, - - - - -	550	0	0
To extra cutting for passing-places, &c. as before, - - - -	48	0	0
To extra land for ditto, as before, - - - - - -	27	0	0
Cut from *Sauchie* new engine to *Tillicoutery Burn Foot*, - - - -	1304	11	0

SUMMARY

SUMMARY of the foregoing estimate.

	£.	s.	d.
Cut from *Tillibodie Bridge* into *Lint Mill Dam*, - - - -	1080	12	0
Cut, &c. at the letter A, - - - - - -	974	19	0
Ditto, at B, - - - - - - -	974	19	0
Cut from *Sauchie* new engine to *Tillicoutery Burn Foot*, - - - -	1304	11	0
Increase of hawling track $1\frac{1}{2}$ mile, at 15*l.* - - - - -	22	10	0
From *Tillibodie Dam* to *Sauchie Cut*, by keeping as much as possible the course of the river,	4357	11	0
Contingencies, at 10 per cent. - - - - - - -	435	14	0
	4793	5	0
By an entire canal, as before, - - - - £. 4712 4 0			
Contingencies, at 10 per cent. - - - 471 4 0			
	5183	8	0
Difference of expence in favour of the river navigation, - - - -	390	3	0

ESTIMATE for continuing the navigation, by Canal, to or near *Alloa*.

If, instead of dropping the cut into the river just above *Tillibodie Bridge*, the level be preserved from the *Coble Crook*, and turned from near *Menstrie Bridge* towards *Alloa*, the increase of distance, according to plan, will be about 2 miles.

	£.	s.	d.
To 2 miles of cut, at 47*l.* 13*s.* 4*d.* - - - - -	762	13	0
To 21,82 acres of land, at 40*l.* per acre, - - - - -	872	16	0
Suppose 2 road-bridges, at 80*l.* - - - - - -	160	0	0
To 4 cart-bridges, at 40*l.* - - - - -	160	0	0
To 2 miles of hawling track, at 15*l.* - - - -	30	0	0
To extra cutting for passing-places, &c. - - - - -	95	0	0
To extra land for ditto, - - - - - -	109		
	2189	9	0
Ten per cent. for unforeseen events, &c. - - - - -	219	0	0
Addition, to carry the cut to *Alloa*, - - - -	2408	9	0

J. SMEATON.

Austhorpe, September 14, 1767.

Lord CATHCART's Queries of the 11th of September, 1767.

To Mr. SMEATON, from Lord CATHCART, September 11, 1767.

IN winter the freſhes and quantities of ice are ſo great, that it is difficult for ſhips to lie in the *Forth*; they are obliged in that ſeaſon to ſhelter themſelves in what is called the *Pow* of *Alloa*; they cannot go up to *Cambus*, nor can boats come down, which would prevent a conſtant intercourſe between the *Devon* collieries and the ſhips in the *Forth*, ſuppoſing the navigation to be made partly in the *Devon*, and partly in cuts from *Tillicoutery* to *Cambus*, where it joins the *Forth*.

There is another method which would be certain and conſtant *, except when the canal was frozen, and is as follows: ſuppoſe Lord CATHCART's aqueduct were to be widened to the proper ſize, from the pipes at *Tillicoutery* to the new engine at *Sauchie*, and from thence carried on upon the ſame level to the weſt end of the town of *Alloa*, it would finiſh upon a bank about 15 feet higher than the pier of *Alloa*, and about 300 yards diſtant from it; from this dead water canal a branch may be carried off, which will be very ſhort, and which will terminate equally on a bank near the *Forth*, a little below the mouth of the *Devon*, from both which banks the coals may be conveyed in waggons to the ſides of the ſhips at *Alloa*, or boats at *Cambus*, which come down the *Forth* from the upper parts of the river.

In this plan there are the following advantages:

There will be no locks; there will be no waſte of water, which will be particularly agreeable to ſome proprietors principally concerned.

The boats may be contracted in width and increaſed in length, and may be very flat, and conſequently the canal much ſhallower and narrower, than if it were to carry boats fit to navigate the *Devon* or *Forth*.

And for theſe reaſons it is ſuppoſed the navigation may be executed cheaper, and with more certainty than in any other method, and may in the ſame manner be carried up the

* Since writing, I have been informed, that the water drawn from the pits, with which the canal before mentioned would be filled, never freezes.

river,

river, as far as proprietors pleafe, on the north bank, although on the upper part there will be a neceffity to have fome locks, as it muft be on a higher level than the under.

Query 1ft. Were fuch a canal to be executed, what would be the proper dimenfions of it, and of the boats, and what would be their burthen?

Query 2d. Would there be any difficulty in carrying fuch a canal over rough ground about *Cobble Brook*, or any danger that it fhould penetrate into the wafte of the *Alloa* coal over which it muft pafs, or that by any little falling in of that wafte, which now and then may happen, the canal may be loft?

N. B. The wafte is 20 fathom below the furface, and there are collieries which do not lie deeper, and are wrought under the fea without inconveniency; but as this danger ftruck the proprietor, it is thought proper to afk the queftion.

Query 3d. How much per mile ought fuch a canal at an average to coft?

ANSWER to Lord CATHCART's Queries of the 11th of September, 1767.

To query 1ft. THE boats proper in my opinion for a fmall canal, is not to make them of extraordinary length, but to make them go in pairs; the fternmoft boat ferving as a rudder to the headmoft boat, which not only gives them a very great advantage in turning, but by keeping them fhort renders them much ftiffer, and confequently fubject to lefs wear and tear.

This method is practifed in all the rivers and canals communicating with the great levels of the fens of *Lincolnfhire*, *Cambridgefhire*, *Norfolk*, &c. where they fometimes go in gangs of four, five, fix, fometimes feven, in a ftring, and where the fecond boat, fteering the firft, is followed by all the reft in the fame curve; their burthen is from 15 tons to 5.

I cannot, however, recommend fo many of them for your purpofe, as your voyages will be fhorter, the returns quicker, will be managed with fewer men and horfes, and in a very narrow canal more eafily directed.

The

The dimenſions I would recommend for your uſe are as follows:

		F.	I.	
The head boat	Extream length, - - -	38	0	Burthen 12 tons.
	Extream breadth, - - -	9	0	
	Draught of water loaded, -	2	6	
The ſtern boat	Extream length, - - -	36	0	Burthen 10 tons.
	Extream breadth, - - -	9	0	
	Draught of water loaded, -	2	4	

Theſe two boats will be drawn with one horſe from 2 to $2\frac{1}{2}$ miles per hour, and will be managed by one man on board.

A canal proper for ſuch boats, ſo as to ſuffer them to draw freely, ſhould be 12 feet bottom, with 3 feet depth of water; the width of the water-line will vary according to the batters; but ſuppoſing thoſe at a medium to be 3 to 5, and the ſurface at a medium 2 feet within ſoil, the ordinary expence per mile, at 3*d.* per yard, will be 242*l.* and the quantities of ground, including cut and cover per mile, will be about 6 acres *Engliſh* meaſure.

Where great hollows are to be filled, or hills to be cut, the extra expences thereof are to be further allowed, as all the charges of aqueduct and common bridges, tunnels, back-drains, towing-paths, &c. to be added; alſo allowance made for paſſing-places, turning-places, &c. which may in a great meaſure be judged of by my report and eſtimate already delivered on the ſubject of the river *Devon*, but cannot be more particular at preſent, for want of plans, ſections, and time.

To query 2d. I don't apprehend any extraordinary difficulty with the rough ground about *Cobble Crook*, more than what happens in like caſes. As to danger from the falling in of the old waſtes of the *Alloa* coal, I don't apprehend they can affect the canal, or the canal affect them, unleſs there happens a fail immediately under the canal which reaches the ſurface; in this caſe, the water of the canal will undoubtedly make its way down into the waſte; but if ſteps are conſtructed at proper places, as is done in the Duke of BRIDGEWATER's canals, no great quantity can go down, and the breach may be repaired ſo as to be water-tight as at firſt; but if waſtes of collieries are ſupported like thoſe which are worked under the ſea, and are not uſed to fall in ſo far as the ſurface, I can ſee no reaſon for this apprehenſion.

Auſthorpe, 8th October, 1767. J. SMEATON.

P. S. I don't

P. S. I don't know that it is a property of coal-pit water *not to freeze*: it is certain that the water from all mines comes out of the earth at about the forty-eighth degree of FARENHEIT's ſcale of heat, it muſt therefore remain unfrozen till by the ſuperior cold of the external air, and ſurface of the earth, it is reduced to thirty-two degrees of the ſame ſcale. If it has any property by which it remains unfrozen, after it's heat is reduced below that degree, it is a peculiarity I am unacquainted with.

MEMORIAL and QUERIES relative to Mr. SMEATON's Report of the Navigation of the *Devon*, of the 14th of September, 1767; from Lord CATHCART, the 14th of March, 1768.

MR. SMEATON, in his report of the *Devon Navigation*, dated September the 14th, 1767, lays down the following propoſition.

That the navigation may be carried up from the *Forth* at *Cambus* to old *Sauchie*, by two methods, which he deſcribes and eſtimates, by making a canal the whole way from *Tillibodie Bridge* to *Sauchie*, or by making a cut from *Tillibodie Bridge* to *Minſtrie Lint Mill Dam*, and making uſe of the bed of the river from thence to old *Sauchie*. Mr. SMEATON eſtimates the expence of this part of the navigation from the *Forth* to *Sauchie* in the firſt manner, that is, uſing the river as little as poſſible, at 5183*l.* and in the ſecond, that is, uſing the river as much as poſſible, at 4793*l.* and though the former, according to his eſtimate, will coſt 390*l.* more than the latter, he prefers and recommends it, for the following reaſons, viz. becauſe the diſtance will be ſhortened 1 ½ miles in 6 ½ miles, and becauſe the works will be in leſs hazard from floods, and will require leſs repair.

The following conſiderations, in favour of the ſecond method, are ſubmitted to Mr. SMEATON, who, when he made his report, was under the diſadvantage of being deprived of papers and memorandums relative to the levels, and other circumſtances of the *Devon*.

1ſt. There is already 4 ½ feet of water in the *Devon*, from the *Lint Mill* as far up as *Coble Brook Ford*, ſo that the work at A, in Mr. SMEATON's Plan, eſtimated at 975*l.*

975*l.* being in water 9 feet deep, cannot be neceſſary, the price of it ought to be added to the balance in favour of the ſecond method, and will raiſe it from 390*l.* to 1465*l.* which is an object.

2dly. From *Coble Crook* to *Hennie's Burn*, a convenient place for boats to lie in, a little below *Sauchie* new engine, there is a riſe of no more than 3 feet 2 inches; at *Coble Crook* there is a foundation of rock, with rocky and ſteep banks on each ſide, and a very good quarry cloſe to it, ſo that there ſeems no reaſon to believe a dam of 3 feet 2 inches high, and a lock of that riſe, can poſſibly coſt a ſum, upon any principle of Mr. SMEATON's other calculations equal, or near equal to 975*l.* but it may be proper to leave that article as it ſtands, becauſe if the people of *Alloa* are cut off from *Alloa*, by the ford being deſtroyed by the dam, there will be a neceſſity to build a bridge over the *Devon*, probably at *Sauchie*, as there is a good foundation and a quarry at hand, which will coſt 200*l.* if ſo, the expence of the ſecond method will remain 3818*l.*

3dly. If the firſt method is uſed, the expenditure of water from the *Tillicoutery Dam*, which ſupplies *Sauchie* engine, will be increaſed by the conſumption of the *Sauchie* and *Collyland* coals, which in the ſecond method would embark in the river above the *Coble Crook Dam*, and would waſte none of the water belonging to the *Tillicoutery Dam*; and it muſt be remembered that the *Sauchie* engine can on no account give up any water which it has or may have occaſion for, and has at preſent a right to.

4thly. The greateſt difficulty attending works now to be carried on in *Scotland*, will be the want of labourers. The execution of the ſecond method will not require above one-ſixth part of the labourers the firſt would require, becauſe the digging is as $\frac{1}{2}$ to 3, and the lockage as $3\frac{1}{2}$ to 20.

5thly. As the *Lint Mill* and *Tillibodie Mill Dams* have been proof againſt the greateſt floods, it may be preſumed that the *Coble Crook* work, which is better placed, and will be better, will be equally ſafe, and will be a ſecurity to the works below.

Query 1ſt. Upon the whole of theſe conſiderations, does Mr. SMEATON admit the deduction of his work at A, and it's expence 975*l.* Does he recommend the canal from *Sauchie* to *Tillibodie Bridge*, or the river from *Sauchie* to the *Lint Mill*; and if the latter, would he place the lock at *Coble Crook*, or at any ſituation above it, in which caſe the *Coble Crook Ford* muſt be deepened?

Propoſition

Propofition 2d. Mr. SMEATON propofes to carry up the navigation from *Sauchie* to *Tillicoutery Burn Foot* by canal, to raife the river by a dam to fupply that canal, to crofs the river and lock up into a cut on the north fide and on the level of *Tillicoutery Dam*, to repafs the river above *Tillicoutery Dam*, and lock up into a cut on the level of the tail-race of the *Rack Mill*, and in that cut to proceed to *Mellock*, and for thefe operations he makes the following charge:

	£.	s.	d.
From *Sauchie* new engine to *Tillicoutery Burn Foot*, - - - -	1304	11	0
From thence, through the river, to the next cut, - - - -	703	7	0
Cut into *Tillicoutery Dam*, - - - - - - -	729	19	0
Cut from thence to *Mellock Foot*, - - - - - -	1044	3	0
Towing Path, at 15 *l.* per mile, for 2½ miles, - - - - - -	37	10	0
	£. 3819	10	0

It is fubmitted to Mr. SMEATON, whether the following method would not be preferable, for the following reafons, viz. To enlarge the *Sauchie* aqueduct to the fize of a canal from the *New Engine* acrofs the road leading to *Tillicoutery Bridge*, to carry it either on the fame level as far as *Mellock*, being 2 miles and a half, and there raife it by a lock to a level of the tail-race of the *Back Mill*, and continue it from thence the fpace of 1 mile further to the tail-race of the faid mill, or by placing the lock nearer *Tillicoutery Bridge*, and raifing the level of the canal earlier, as may be thought moft convenient;

1ft. Becaufe this work will be entirely out of the reach of the higheft floods, and the works at *Tillicoutery Burn Foot*, the moft precarious and expenfive, in point of repairs, in the whole navigation, will be faved, and the price of it being 703 *l.* will probably more than anfwer the extra expence of carrying a canal along the fouth bank of the river, betwixt *Tillicoutery Bridge* and *Tillicoutery Dam*, where the ground is more narrow and difficult, as well as the additional length of canal beyond Mr. SMEATON's calculation, amounting to 6 furlongs, which, it is apprehended, will require lefs expence in digging and in land than the fhorter place, which is propofed to run through ground much more valuable, and to be cut much deeper within foil, efpecially betwixt *Sauchie* and *Tillicoutery Burn*.

2d. Becaufe by keeping the canal 20 feet above the level of the river at *Hennies Burn*, it may be, with the fame expence, communicated by locks at that point, as if the lockage had been difperfed along the whole courfe of it; and if either money or

 hands

hands ſhould fall ſhort, the execution of theſe 20 feet of lockage might be poſtponed, and an immediate communication opened, for the time being, betwixt boats coming up the *Devon*, as far as *Sauchie* from the *Forth*, and boats coming down from the *Rack Mill* to *Sauchie*, till the junction is compleated by locks.

3d. Becauſe, by carrying up the navigation 1 mile beyond *Mellock*, no additional lockage will be incurred, as the lock neceſſary is marked in Mr. SMEATON's plan, and the expence included in his eſtimate; ſo that the additional expence will be no more than the digging, land-bridges, and towing-path of 1 mile, amounting, according to Mr. SMEATON's eſtimate, to 769 *l.* and the benefit of water carriage will be communicated to *Dollar* and the country above it, as there is now a bridge at the *Rack Mill*, and to the *Blairngon Colliery*, to which a road for the carriage of coal may eaſily be made; and it is ſuppoſed that the produce of that colliery, whether carried to the ſea or to the north country, would go down the *Devon*, which would both increaſe it's produce and raiſe it's tolls.

Query 2d. Is Mr. SMEATON of opinion, that the navigation ought to be carried up to *Mellock* in the manner above deſcribed, keeping the ſouth ſide of the water the whole way, and that the expence will not exceed the above eſtimate of 3819 *l.* 10 *s.*? That it ought alſo to be carried up to the *Rack Mill?* and that the additional expence will not exceed 769 *l.*—in all 4588 *l.* 10 *s.*? To which ſuppoſing 3818 *l.* to be added, for the ſpace betwixt *Cambus* and the *Sauchie*, the two ſums will make 8406 *l.* 10 *s.* and with 843 *l.* 10 *s.* for extraordinaries, the whole expence of the navigation from *Cambus* to the *Rack Mill*, for boats drawing 3 feet water, will amount to 9250 *l.* according to the principles of Mr. SMEATON's eſtimate.

Query 3d. As the boats deſcribed by Mr. SMEATON, drawing 3 feet water, are only fit to go down the *Forth*, as far as *Carron*, with which the *Devon*, as both their produce in coal cannot have much intercourſe, it is deſirable that a foot of additional depth ſhould be given to the works below *Sauchie*, in order that they may be paſſable for boats drawing 4 feet water, 13½ feet wide, 42 feet long, and carrying 25 tons; ſuch boats being conſtructed in the *Clyde*, for the navigation of the highland ſeas, and therefore ſuppoſed fit to go to *Leith*, and in ſummer to the north country: Query, What additional expence would this alteration coſt? It is ſuppoſed, that if a foot were to be added to the *Lint Mill* and *Tillibodie Mill Dams*, the river would ſtill be within ſoil, and would require no banking, and, if ſo, that a foot more water would be

be thrown into the two cuts without any farther expence for extra digging, and that in the river there is a ſufficient depth.

Query 4th. What would be the expence per mile of deepening the canal 1 foot between *Sauchie* and the *Rack Mill?*

Query 5th. The ground being favourable for cutting a canal, on a dead level, from the *Lint Dam* to *Stirling Bridge*, where it might be communicated, by a lock or locks of 11 feet fall, with the *Forth*, it would be proper to include this circumſtance in the act of Parliament, becauſe not only all the coals for the north country ſale would be conveyed by it to *Stirling Bridge*, but alſo the *Upper Forth* boats coming to the *Devon* for coals would lock up at *Stirling Bridge*, rather than *Cambus*, as they would ſave near 12 miles each trip; the expenditure of water would be diminiſhed rather than increaſed, becauſe the lockage is not computed at more than one lock-full per day. The coals for the north country and for *Stirling* would waſte no water, which they muſt do were they to go down the *Devon* and up the *Forth*, and the boats coming and going from and to *Craigforth* would waſte the ſame water, whether they entered the canal at *Stirling Bridge* or the *Devon* at *Cambus*. Mr. SMEATON eſtimates 2 miles of canal between *Menſtrie Bridge* and *Alloa*, at 2400*l.* and the lockage from the level of the former into the *Forth* of the latter, at 1100*l.*—in all, 3500*l.* Query, The height being the ſame, and the diſtance one third greater, is not 4700*l.* an adequate price for the branch from the *Lint Mill Dam* to *Stirling Bridge*, being 3 miles in length, and for the lockage into the *Forth?* viz. together with the former ſum of 9250*l.* would make in all 13950*l.* for the navigation of the *Devon*, and for the branch to *Stirling*.

PERTH

PERTH BRIDGE.

MEMORIAL for Mr. SMEATON.

August, 1763.

THE Juſtices of Peace for the county of *Perth*, at their quarter ſeſſions in May laſt, having entered into ſeveral reſolutions to promote a ſcheme for building a bridge acroſs *Tay*, at or near *Perth*, did, among others, appoint a committee of their number to meet with and conſult Mr. SMEATON on this ſubject.

Theſe gentlemen now take this opportunity of applying to Mr. SMEATON, that he will viſit and inſpect the river at and near the town of *Perth*, and report to them the proper place for erecting ſuch a bridge, paying alwiſe a particular attention to the ſafety of the town of *Perth* and the adjacent grounds, as well as the bridge.

He will be pleaſed, at the ſame time, to conſider how far a ſtable bridge, of any other materials than ſtone, can be conſtructed, ſo as to anſwer all the requiſite purpoſes of carriages, &c. and be made more properly adapted to the ſituation and rapidity of the river and ſafety of the town.

As Mr. SMEATON will ſatisfy himſelf as to the meaſures of the breadth of the river at the different places, it is only neceſſary to obſerve, that the land-floods often ſwell the river, with great rapidity, 14 feet higher than the water is in ſummer, and that the ſtream-tides flow to the height of 8 feet, or thereby, oppoſite to the *North Key*, where the former bridge was built, and that the bed of the river is generally hard gravel.

If Mr. SMEATON ſhould approve of the ſcheme, and determine on the ſituation, it will be proper that, with conveniency, he make a plan of ſuch bridge as he ſhall judge moſt eligible; for which plan, and his trouble in viſiting the river, the committee will properly gratify him.

The

The REPORT of JOHN SMEATON, Engineer, concerning the practicability of building a bridge over the river *Tay*, at *Perth*, in anſwer to a memorial thereupon addreſſed to his conſideration by the committee of Juſtices, bearing date Auguſt, 1763.

HAVING, purſuant to my inſtructions contained in the ſaid memorial, examined the ſoundings of the river *Tay*, at and near the town of *Perth*, in the month of Auguſt laſt, as well as other circumſtances relative thereto, I am of opinion as follows:

1ſt. That from the rapidity of the river, and the quantity of ice, ſaid to come down the ſame in winter, that though a bridge may be built of timber ſufficient to anſwer the purpoſe for a number of years, yet, to give the ſame the neceſſary degree of ſtability, will, in it's firſt erection, be near as expenſive as if built with ſtone, and, from the periſhableneſs of the materials, be ſubject, in the courſe of a few years, to great and expenſive repairs; and withal conſidering that this is a part of the country where good workable and durable ſtone is cheap, and good oak timber dear, I can by no means recommend a bridge of any other materials than of ſtone.

2d. I am of opinion, that it is practicable to build a durable and uſeful ſtone bridge at or near the town of *Perth*, and without any danger or hazard to the town likely to ariſe therefrom, provided it be conſtructed with a ſufficiency of water-way.

3d. I am of opinion that two of the moſt proper places for the ſituation of a ſtone bridge is either in a right line with the *Town Street*, nearly where the old * bridge was erected, or a little above the town, from the *Tenter* in the *North Inch* to the oppoſite ſhore in *James Biſſett*'s garden.

4th. Of theſe two places, I prefer the latter, on account of leſs difficulty and leſs expence; for though the river is wider at the latter ſituation than at the former; yet, as the depth is conſiderably leſs, the expence and hazard of making coffer-dams for laying the foundation of the piers, will be very conſiderably greater oppoſite the town than at the *North Inch*; and the expence of making dams and clearing the foundation will

* Built by *John Mylne*, and ſwept away (in 1621) by a mighty inundation.

be

be further enhanced by the remainder of the old piers, all or moſt of whoſe foundations probably remain in the river.

5th. In conſequence of this preference, I have made a deſign for a ſtone bridge to be erected from the tenter at the *North Inch* to the oppoſite ſhore, which accompanies this report, and have alſo annexed an eſtimate of the expence; the width of the river here I make to be about 653 feet.

6th. It is to be remarked, that it appeared to me, from ſounding, that the bed of the river was every where a firm gravel, ſufficient to ſupport the weight of ſuch a bridge as I have propoſed; but from information I learnt, that, in digging near the river, there is every where a ſtratum of ſandy clay, laying about 4 feet under the bed of the river, and about 4 feet thick: now, as ſome excavation in the bed of the river will be neceſſary, this will reduce the upper cruſt of gravel ſo thin, that the ſtratum of ſandy clay, being of a yielding nature, the bridge cannot with ſafety be truſted upon it without piling, nor even with piling ſo ſecurely; nor can it be done at ſo ſmall an expence as by carrying the foundation down to the ſurface of the under-bed of gravel, which is ſaid to reach to an unknown depth. For theſe reaſons, I have ſuppoſed the foundation of the bridge to be laid 8 feet under the bottom of the deepeſt part of the river, where the bridge is propoſed to be fixed, and have eſtimated the expence accordingly; but if it ſhould turn out, on boring or digging, that the upper ſtratum of gravel is conſiderably *thicker* than here ſuppoſed, or that no ſuch ſtratum of ſandy clay ſubſiſts at this place, then a conſiderable expence will be ſaved, the foundation being here ſuppoſed to be laid 10 feet under the ſurface of the river at low water in dry ſeaſons. On this account, I would adviſe the foundations to be tried before any thing definitive be determined.

7th. It is to be further remarked, that the prices in the following eſtimate are ſuch as are uſual for ſuch kind of work in this part of the kingdom, and ſuch as I apprehend it may be done for at *Perth*; but, for further ſatisfaction, if the committee pleaſe to order my eſtimate to be drawn out, with the quantities there inſerted, without the prices, they will have an opportunity of having the ſentiments of the workmen of the country thereupon, by cauſing them to fill up the ſame; only regarding the coffer-dams, as the method therein propoſed cannot be explained without models, nor indeed ſucceſsfully practiſed but by a perſon experienced therein; their ſenſe thereupon will be beſt had, by ſtating the internal circumference of the dams, and that they are, at a medium, to pen out 6 feet water: the committee will thereby come at the coſt thereof in ſuch method as the workmen themſelves would propoſe; but, as the method is put in daily practice

practice here, the committee may depend on it's being practicable, and at the prices ſtated, unleſs there is a material difference in the value of timber and labour here and at *Perth*.

ESTIMATE for erecting a Stone Bridge over the river *Tay*, at *Perth*, from the *Tender* at the *North Inch* to the oppoſite ſhore; to have 7 principal arches, extending 605 feet 9 inches, and in the whole length 893 feet; to be 22 feet in the clear, within the parapets, and to have a walking path on the ſouth ſide of 4 feet wide.

By JOHN SMEATON.

COFFER DAMS.

THERE being, according to my information, a ſtratum of hard gravel at the depth of 8 feet below the bed of the river, I propoſe to found the piers immediately thereupon, without piles or grating; and in order to come at this foundation, as the river will not in it's low ſtate be above 2 feet deep of water, and does not riſe at ordinary ſpring tides more than 8 feet above this mark, and at neap tides little worth regarding, I reckon that a dam, capable of holding out the water 4 feet above it's low ſtate, will enable the workmen to work nine or ten days ſucceſſively between each ſpring tide; and I apprehend a dam of this height will not only be conſtructed at a much leſs expence, but be leſs ſubject to hazard, than if raiſed ſo as to pen out the ſpring tides; this dam to have a ſluice upon it, to let the water in and out, as occaſion ſhall require; and, for the more ſafe and ready excavation of the matter, I propoſe the dam to be placed at a medium 16 feet diſtant from the baſe of the pier, and to be of an elliptical figure, the better to reſiſt the tides and floods.

	£.	s.	d.
To 26 gage piles, of 10 feet long, at 10 *s.* each, - - -	13	0	0
To 2328 feet ſuperficial of plank piling, 9 ½ feet long, at 1 *s.* 2 *d.* -	135	16	0
To 122 cube feet of timber, in ſtring pieces, for ſupporting the pile heads, at 3 *s.* - - - - - - - - -	18	6	0
To extra work, in making a ſluice for letting the water in and out, -	2	10	0
To timber work in one coffer dam, - - - - - - -	£. 169	12*	0

* In the eſtimate delivered in, this number was by miſtake called 2 inſtead of 12 *s.* and the dependent ſums being leſs accordingly, made the articles of the coffer dams be 724 *l.* 2 *s.* inſtead of 726 *l.* 2 *s.*

	£.	s.	d.	£.	s.	d.
Brought forwards,				169	12	0
To pile ſhoes, for 26 gage piles, at 1 *s.* each,	1	6	0			
To plank pile ſhoeing, 245 running, at 6 *d.*	6	2	6			
To 25 bolts for the ſtring pieces, at 2 *s.* each,	2	10	0			
To extra iron-work about the ſhuttle, and contingencies,	2	0	0			
To iron-work about one coffer dam,				11	18	6
A coffer dam complete,				181	10	6
The materials for the firſt pier is ſuppoſed to be of half value toward each ſucceeding pier, which will therefore be No. 6. at 90 *l.* 15 *s.* 3 *d.* each,				544	11	6
Coffer dams for the whole				726	2	0

Excavation and drainage.

	£.	s.	d.	£.	s.	d.
To excavation of the matter 722 yards, at 6 *d.* comes to, each pier,	18	1	0			
To drainage of the water, ſuppoſed equal to 50 days, at 20 *s.* per day, per pier,	50	0	0			
To excavation and drainage of 6 piers, the 2 abutment piers, and foundation for the wing walls, being ſuppoſed equivalent to 2 piers, the whole will be equivalent to 8 piers, at 68 *l.* 1 *s.* each,	68	1	0	544	8	0

Maſonry in the piers and abutments below the ſpringing of the arches.

	£.	s.	d.	£.	s.	d.
To 1080 feet ſuperficial of aſhler in each pier below water, at 7 *d.*	31	10	0			
To 1176 ditto above water, at 8 *d.*	39	4	0			
The whole pier, in ſolid, contains 467 cube yards, including labour, carriage, tarras mortar 6 inches in the outſide joints, and all materials, at 5 *s.* per yard,	116	15	0			
N. B. The aſhler being at leaſt 20 inches bed, and cubed into the ſolid, at 5 *s.* per yard, is ſuppoſed to pay for the tarras mortar and extra labour in ſetting thereof.						
To capping the pier with ſolid blocks jointed between the ſpringer ſtones, 600 cube feet, at 6 *d.*	15	0	0			
To capping the ends of the piers 148 feet ſuperficial, at 8 *d.*	4	18	8			
To 6 piers, and 2 abutment piers, each reckoned as a pier, that is No. 8, at 207 *l.* 7 *s.* 8 *d.*	1659	1	4			
To walling-in the weſt land ſtool to bring it up to the ſpringers, to be at a medium 5 feet thick, containing 490 cube yards, at 5 *s.*	122	10	0			
To hammer-dreſſing that part of the wall that comes in view below the plinth, containing 666 feet ſuperficial, at 1½,	4	3	3			
To working the plinth, being before reckoned as ſolid, containing 990 feet ſuperficial, at 3 *d.*	12	7	6			
To 78 cube yards of maſonry in the eaſt land ſtool, to bring it up to the height of the ſpringers, at 5 *s.*	19	10	0			
To ſetting under the weſt abutment arch to prevent the water from affecting the foundations, 1353 feet, at 4 *d.*	22	11	0			
Maſonry in the piers and abutments below the ſpringing of the arches,				1840	3	1

Centering for the arches.

To timber in one rib, 416 cube feet, and for 6 ribs -		2496 cube feet.						
To timber in 30 bearing piles, and 5 capt-trees for supporting the ribs, - - - - - -		750						
To stays and bracings between the ribs to keep them upright		75						
To covering for the centers in square scantlings - -		525						
To additional work to make the centers fit the larger arches,		188	£.	s.	d.	£.	s.	d.
To timber in a center compleat, at 3 *s*. per foot, -		4034	605	2	0			
To ironwork in the six ribs, 1852 lb. at 5 *d*. -	£. 38 11 8							
To ditto in pile-shoes and hoops, 662 lb. at 5 *d*.	13 15 10							
To spikes, nails, and other contingent articles, -	5 0 0							
To ironwork for one center, - - - - - -			57	7	6			
To one center compleat, - - - - - - - - - -						662	9	6
To a set of piles and cap-pieces ready prepared for driving in the second arch before the first center is struck, containing 750 feet, at 2 *s*. - - - - - -						75	0	0
To 5 booms, containing 375 feet of timber, at 2 *s*. to be fixed as struts between the piers of the second arch, while the center is taking down from the first, and putting up in the second,						37	10	0
To taking down the center, drawing the piles, driving ditto, and setting up the center six times, repairing and making good what is wanting, at 9 *d*. per foot solid upon the timber, which being 4034 feet, comes to 151 *l*. 5 s. 6 *d*. each time, and for six times, -						907	13	0
To taking down and putting up the booms five times, at 6 *d*. per foot, - - -						46	17	6
To centering for one of the small arches, at 1 *l*. per square, - - - -						20	0	0
To taking down, removing, and setting-up ditto in the other arch, - - -						5	0	0
Centering for the bridge, compleat, - - - - - - -						1754	10	0

Masonry in the superstructure.

To 15850 feet superficial in the soffite of the main arches, being three feet thick, set in place, and mortar included, at 20 *d*. - - - - - -	1320	16	8
To 2000 feet superficial in the soffite of the abutment arches, at 12 *d*. - - -	100	0	0
To blocking up the spandrils of the arches solid, 6 feet high, containing 473 cube yards, at 5 *s*. - - - - - - - - - -	118	5	0
To cube masonry in the spandril walls, abutments, and wing walls, from the top of the piers to the top of the cordon, containing 3776 yards, at 5 *s*. - - - - -	944	0	0
To hammer-dressing the plain superficies thereof, containing 33984 feet, at 1½ - -	212	8	0
In the parapet 11856 feet superficial on both sides, being 15 inches thick, stone, workmanship, mortar, and setting ditto, at 6 *d*. - - - - - -	269	8	0
To 18382 feet superficial in the faces of the arches, bands, and keys, the cordon, mutules, capping, and pedestals, which being before reckoned in solid, except their projecting parts and all square work, I put at 4 *d*. per foot, - - - - -	306	7	4
Carried forwards	3271	5	0

	£.	s.	d.
Brought forwards -	3271	5	0
To 2160 feet ſuperficial in the 12 eyes, and 640 feet in the terminating pillars, in the whole 2800 feet ſuperficial of circular work, (being before included in the ſolid) at 6*d*. -	70	0	0
The walking-path, being 4 feet wide, contains 3641 feet ſuperficial, ſtone, working, and laying, at 7*d*. - - - - - - - - -	106	12	0
Maſonry in the ſuperſtructure, - - - - -	347	17	0

GRAVEL.

	£.	s.	d.
To 10948 cube yards of gravel to fit up the ſpandrils and wing walls, and form the road, at 9*d*. per yard, - - - - - - - - - -	410	11	0

N. B. No part of the road is conſidered except what falls within the walls of the bridge.

CONTINGENCIES.

	£.	s.	d.
To piling engines, pumps, and other utenſils, ſuperviſal, unforeſeen accidents, and expences,	1000	0	0

ABSTRACT.

	£.	s.	d.
To coffer dams, - - - - - - - -	726	2	0
Excavation and drainage, - - - - - - - -	544	8	0
Maſonry in the piers and abutments below the ſpringing of the arches, - -	1840	3	1
Centering for the arches, - - - - - - -	1754	10	0
Maſonry in the ſuperſtructure, - - - - - - -	3447	17	0
Gravelling the bridge, - - - - - - - -	410	11	0
Contingencies, - - - - - - - -	1000	0	0
Total -	9723	11	1

N. B. In the batterdeaus and centers there will remain at leaſt 5763 cube feet of timber, which, if ſold for 9*d*. a foot cubic, will amount to 214*l*. 2*s*. 3*d*. beſides ironwork, engines, and utenſils, which, it is preſumed, will be ſufficient to make the road to and from the bridge.

The prices in the preceding eſtimate includes all labour, carriage, mortar, and ſetting-up in place, unleſs otherways particularly expreſſed.

EXTRACT

EXTRACT Minutes of the Truſtees for building a Bridge over the *Tay*, at *Perth*.

AT *Perth*, the 26th day of September, 1765 years, at a meeting of the truſtees for building a bridge over *Tay*, at *Perth*, four letters from Mr. SMEATON to the Earl of KINNOUL, dated 12th of July and 1ſt of Auguſt, 1764, and 9th of April and 3d of May, 1765, being read, upon conſideration thereof, and of the ſums ſubſcribed in free gift towards building the bridge, it is the opinion of this meeting:

1ſt. That the work ſhall be begun next year, by raiſing an experimental pier, under the direction of Mr. SMEATON, as propoſed by him, and that the materials neceſſary for raiſing ſuch a pier be prepared in due time.

2d. That Mr. JOHN ADAM, architect, is a proper perſon to be employed in preparing ſuch materials.

3d. That Mr. ADAM be deſired and authoriſed to open, and try, proper and convenient quarries for that purpoſe.

4th. That a committee be appointed to confer and treat with Mr. ADAM, and to receive propoſals from him concerning ſuch materials, which propoſals he is deſired to lay before the Committee.

5th. That the ſaid Committee ſhall, from time to time, as they ſhall think proper, report their proceedings to a meeting of the truſtees, and that the clerk ſhall call a meeting for that purpoſe, whenever the ſaid committee, or any two of them, ſhall deſire it.

6th. That the Earl of KINNOUL; Lord GRAY; Mr. CRAWFORD, of *Errol*; Mr. GREENE, of *Balgovan*; Sheriff SWINTON; Mr. BELCHES; Provoſt SIMPSON; Mr. OLIPHANT, of *Roſſie*; Mr. CRAIGE, of *Dumbarney*; Meſſrs. ROBERTSON, elder and younger, of *Tullibeltan*; Mr. RICHARDSON; Mr. MERCER; Mr. WOOD, Dean of *Guild* SANDEMAN; Baillie FYFE; Mr. WILLIAM SANDEMAN; Baillie RAMSAY; Baillie MARSHALL; Baillie FAICKNEY; Mr. THOMAS ANDERSON, and other Truſtees that ſhall pleaſe to attend, ſhall be of the ſaid Committee; and that five ſhall be a quorum; and that Mr. MERCER ſhall be convener.

7th. That

7th. That the clerk ſhall tranſmit extracts of the foregoing reſolutions to Mr. SMEATON and Mr. ADAM. Extracted from off the record of the minutes of the ſaid Truſtees, by

PAT. MILLER, Clerk.

EXTRACT Minutes of the Commiſſioners for the Bridge over the *Tay*, at *Perth*, in relation to Mr. JOHN GWINN trying the foundation, &c. and his report, 1766.

AT *Perth*, the 27th day of February, one thouſand ſeven hundred and ſixty-ſix years, ſederunt, the Earl of KINNOUL, Provoſt SIMPSON, Mr. MERCER, Mr. WOOD, Baillie MARSHALL, Mr. WILLIAM SANDEMAN, Mr. DUNCAN, Mr. ALEXANDER FAICKNEY, Mr. THOMAS ANDERSON, and Mr. SAMUEL SAMPSON, commiſſioners appointed by Act of Parliament for building a bridge over the river *Tay*, at *Perth*.

The Earl of KINNOUL choſen Præſes.

The committee appointed by the commiſſioners the 26th day of September laſt, gave in the following report of their proceedings, to wit,

At Perth, the 20th day of February, faiery ditto, and ſixty years, at a meeting of the committee of the commiſſioners for the bridge over the *Tay*, at *Perth*, ſederunt, the Earl of KINNOUL, Provoſt SIMPSON, Mr. MERCER, Mr. WOOD, Mr. JAMES DUNCAN, Mr. THOMAS MARSHALL, Mr. ALEXANDER FAICKNEY, Mr. THOMAS ANDERSON, the Earl of KINNOUL Præſes.

The committee having communed with Mr. GWIN, the perſon recommended and ſent by Mr. SMEATON, direct him to continue boring at that place, which Mr. SMEATON pointed out to be the propereſt place for the bridge, according to the opinion he had formed when he ſurveyed the river, until he has diſcovered, as well as he is able, the metals that are to be found in the bed of the river, the whole way acroſs the ſame, and that he would likewiſe bore acroſs the river oppoſite the town-houſe, and in any other part he ſhall think proper to try; and that he will report to the commiſſioners, at their meeting the 27th inſtant, what place he in his judgment, upon full conſideration of all circumſtances, and upon the beſt information he can get of the

ſtate

ſtate of the river at the different parts in the time of ſpeat, thinks the moſt eligible for erecting the bridge, with his reaſons for ſuch opinion; and that he will alſo report the particular ſtate of the metals as he ſhall find them at the different places by his boring, and that he ſhall likewiſe include in the ſaid report a particular of the materials he ſhall think neceſſary in his branch of buſineſs for erecting the experimental pier this ſummer, always underſtanding that Mr. SMEATON is willing that ſuch pier be erected in the moſt difficult part of the river, and alſo what number of hands it will be neceſſary for him to employ in his branch, in order to prepare every thing for erecting ſuch pier as early this ſpring as the ſtate of the river will admit; and Mr. SMEATON's other engagements will allow him to come here for that purpoſe, diſtinguiſhing what men he thinks it abſolutely neceſſary to bring with him, and the terms upon which ſuch men may be engaged, and what number of hands he would have engaged here; and laſtly, that Mr. GWIN will acquaint the commiſſioners at what time he propoſes to return, to begin theſe preparations.

The committee order the clerk to communicate to Mr. GWIN Mr. SMEATON's plan, eſtimate, and report anent the bridge, with his letters to the Earl of KINNOUL, and alſo to the clerk there anent.

The committee empower Mr. MILLER, their treaſurer, to defray the expence of quarrying the ſtones, and to pay Mr. GWIN ſuch ſums as ſhall be neceſſary for preparing the works which he is engaged in, and for providing materials.

The committee direct the treaſurer to draw upon Mr. ANDREW DRUMMOND for ſuch ſums as he ſhall inform him, from time to time, are in his hands, and to remit the ſame to the bank at Edinburgh, with the profits of the exchange.

The committee direct the treaſurer to remit to the bank ſuch ſums as ſhall come into his hands, in the moſt proper manner.

The committee appoint that theſe their proceedings to be reported to the next meeting of the commiſſioners.

(Signed) KINNOUL, P.

The clerk produced a copy of a letter from Mr. SMEATON to the Earl of KINNOUL, dated the 6th inſtant, and alſo two letters from Mr. SMEATON addreſſed to the clerk, dated the 6th and 10th inſtant, all of which were read.

Mr.

Mr. GWIN gave in to the meeting his report, of which the tenor follows:

The REPORT of JOHN GWIN, in anſwer to orders by him received, and appointed to his inſpection and conſideration at a meeting of the commiſſioners for building a bridge over the river *Tay*. February 27, 1766.

1ſt. UPON ſounding with what inſtruments was practicable to get down to prove the ſtratum of matter in ſundry places acroſs the river *Tay*, from *North Inch* to the oppoſite ſhore in JAMES BISSET's garden, as well as the ſtate of the river and metals would permit, find the ſtratum of matter in the different ſoundings are as follow: that on ſounding and boring in ſundry places both above and below JAMES BISSET's garden, to the extent of about 150 feet in length up and down ſtream, found a rock cloſe in ſhore upon an average lying upon 2 feet 9 inches below the top ſurface of the gravel, and extending itſelf from the ſhore, towards *North Inch*, as near as I could judge, about 300 feet, before I could exactly ſay I thought it left, and continued to be very level, not varying one foot in depth in the above length. This top cruſt, or ſuppoſed ſtratum of rock or hard cemented gravel, conſiſts equally alike in all different places of trial by boring, and appears to be a ſhaly hard conſiſtence for about 8 inches thick; but upon further ſpeculation, to prove its conſiſtency of metal, found that we could force a ſharp-pointed iron bar down 6 feet deep (in ſome parts 8 feet deep) into the ſaid ſtratum of ſhaly matter, always obſerving the bar went moderately eaſy after it got through the upper cruſt beforementioned, and did not begin to faſten till at about 8 feet or 9 feet in general, and then it came to a matter much more firm and ſolid. From this place, which is not quite the half over to the *North Inch*, the ſtratum grows ſomewhat ſofter after we got down 7 feet from the top ſurface, which ſeems to run, on a medium, nearly on a level, it being a ſtratum of ſound firm gravel, and then, for about 2 feet 9 inches, it appears to be a ſandy gravel, (by what our rods brought up) and under that, at about $10\frac{1}{2}$ feet from the top ſurface, on an average, we come to a firm ſound gravel, as before.

Upon boring on the ſhore in JAMES BISSET's garden, in two places, at the diſtance of 30 feet from the water's ſide, find the ſtratum of matter to be from the top ſurface to 6 feet deep a blue corn mold earth, and from that down $5\frac{1}{2}$ feet a quite ſhear ſand intermixed with a little gravel, which both together makes 11 feet 6 inches, at which depth we came at the rock, which lies nearly level, and riſing in its bed but very little up the hill. On the *North Inch* ſide on land we bored, we find corn mold earth to the depth of 5 feet from the ſurface, and from that to the depth of 3 feet a ſharp ſhear ſand, then came to a looſe gravel for about 2 feet, after which it continues looſeiſh to about the depth of 8 feet, at which depth it appears to be a quite ſolid gravel, and is all the particular

particular ſituations of the ſtratum of matter conſiſting in the bed of the river, acroſs from ſhore to ſhore, at the abovementioned place, to the beſt of my opinion.

2d. Upon ſounding the aforeſaid river from the town-houſe to the oppoſite ſhore called bridge end, find the metals in the bed of the river as follows. Having drove a ſharp pointed iron bar in ſundry places up and down ſtream for near 120 feet in length, but could find no place to get the bar down from the upper ſurface about 4 feet before it met with ſome of the ruins of the old bridge, which lay ſpread up and down in that channel for about 60 yards facing the high ſtreet, and extending about 80 or 100 feet breadthways acroſs the river; after which, on ſounding from thence to about 80 feet of the oppoſite ſhore in ſundry different places, found the ſtratum of matter ſo ſoft, as to admit a bar being forced eaſily down into it 12, 14, and 16 feet, and even at that depth no ſolid matter appeared. The ſoil, from what I can judge, is a ſandy clay, at about 6 or 7 feet from the top ſurface, which is all the particular deſcription of the ſtrata of matter in the above ſituation, to the beſt of my opinion.

3d. Regarding which of the two before-mentioned places is propereſt to erect the bridge, my opinion is, that the ſuitableſt place for the bridge to be built near the town of *Perth*, is from the *North Inch* to the oppoſite ſhore, in JAMES BISSET's garden, (for reaſon 1ſt.) The river is more extenſive in breadth than in any other place adjacent to the town. (2dly.) In extreme floods the water having liberty to extend itſelf to a great ſurface, and by the intended ſituation of the bridge being at a proper diſtance from the mill lead, conſequently will give room and ſcope for a great quantity of water to iſſue in there on the down-ſtream ſide of the bridge, which will cauſe a lethe of water to conſtantly be recoiling back to the bridge, and meet the currency, and thereby eaſe in a great meaſure the preſſure and weight on the bridge. (3dly.) Its ſituation in this place is much more deſirable, as it is acroſs a ford, which by the beſt accounts I can learn has not been known to ſhift theſe many years. (And laſtly.) It has been remarked, that during the late ſtorms, wherein the *Tay* has diſcharged great quantities of ice, which has floated up and down with the tide, it was not known that ſcarcely any ice went up above the ſaid ford, but has been known to gorge up the river in different places to an almoſt incredible height below the ſaid ford, particularly at or nearly oppoſite the town-houſe, which would be a very great obſtruction to the water-way in a flood time, provided the bridge was pitched upon to be built acroſs this part of the river; beſides, another reaſon in my opinion againſt this ſituation not being ſuitable is, that the river is more contracted from ſhore to ſhore, it being but 567 feet acroſs from the town-houſe wharf to THOMAS TYFF's houſe, beſides its bounds are ſhorter than that, as much as it is acroſs from the wharf ſide to his houſe, which is 34 feet, which reduces the water-

 way

way ſo much leſs; and (3dly,) on continuing the proper length of the bridge, find that according to plan the bridge foot will terminate above 50 feet above *Waller Gate Street*, which will render the low rooms of the dwellings contiguous thereto invalid, by the bridge being ſo high above them on both ſides, ſuppoſing all other circumſtances agreed with its ſituation.

4th. Regarding the part of the river in which the firſt pier ſhould be fixed, am of opinion, that one of the center arch piers will be as difficult as any, for reaſon, if we are to go down to that lower bed or ſtratum of hard gravel, it will be a difficult matter to drain it, for the getting out the excavation and foundation laying, or the third pier neareſt the bridge end ſhore, it being the deepeſt water there.

5th. Regarding the quantity and quality of ſundry materials in timber neceſſary for the erection of one pier, in making a coffer-dam and pumps and engines, and all other materials, &c. ſuch as tackles and ſhear-poles for the maſonry, and hand and wheel barrows for the excavation, and likewiſe, in caſe the pier ſhould be ordered by Mr. SMEATON to be piled in the foundation, the ſtuff wanted will be as followeth: for the coffer-dam and other uſes 2274 cube feet of oak and elm, and 150 cube feet of *Riga* timber, about 200 ſuperficial feet of aſh plank for barrows, about 15 *Aſſar* baulks, 20 feet long, for ſtages, and tackle poles, &c. about 30 *Dantzick* 3 and 4 inch planks, 20 feet long, for ſtages and runs for the barrows in the excavation, likewiſe about 30 inch and half *Dantzick* planks for engines, and pumps, &c. about 14 or 16 feet long; and laſtly, if it comes to be a timber foundation, (not that I pretend to know in what manner Mr. SMEATON will pitch on it to be done,) but only in caſe it ſhould ſo happen that he thinks it neceſſary; in ſuch a caſe, I have made a rough calculation what ſtuff we ſhould have in readineſs againſt ſuch thought as may to him ſeem beſt, which appears it cannot be leſs than 1000 cube feet of oak and elm, though I think it would be full enough, only it would be proper to have ſome to turn our hands on.

Regarding what number of my workmen I think neceſſary to bring with me from *England*, I intend to bring two men and my apprentice. As to terms, Gentlemen, as they will be employed in your ſervice about five months, or nearly ſo, and then have to go home back again, I think I cannot engage them otherwiſe than at 14*s*. per week each man, and the apprentice to be 7*s*. with their time and moderate expences on the road going and coming paid them.

7th. Regarding the quantity of other workmen neceſſary in my branch for carrying on the pier, to be aſſiſting with my men, I think four carpenters and ten labourers will

be

be sufficient for the expediting the work; but the latter will not be wanted till we begin to take off the water.

With the blessing of God, if I continue in good health, I propose to be at *Perth* in six weeks time, from the setting off on my journey to my coming again, provided all materials, or part to begin, be got to a proper place to work, upon notice, which I presume will be sent; and I think, if agreeable to you, Gentlemen, that Mr. SANDEMAN's saw-mill will be the properest place to work up the materials, as the stuff may be sawed by the mill and worked up there, and then sent down to the work by water as wanted, and not be liable to be any of it lost by floods.

Signed, JOHN GWIN.

Which report being read, the Commissioners direct Mr. GWIN that he will immediately, upon his return to *England*, communicate the said report to Mr. SMEATON, and desire Mr. SMEATON to ascertain the materials which he shall think most proper and necessary for the timber work that is to be prepared for erecting the experimental pier; and that he would, as soon as possible, transmit to Mr. PATRICK MILLER an account of the materials so ascertained by him.

The Commissioners approve of Mr. GWIN's terms upon which he proposes to bring down from *England* the two workmen and his apprentice.

The Commissioners recommend it to Mr. GWIN to regulate his return so that the necessary preparations may be ready at the time it will suit Mr. SMEATON's convenience to be here; and they direct their clerk to deliver to Mr. GWIN a copy of their minutes in so far as relates to his report.

Extracted from the records of the said Commissioners by me

PAT. MILLER, Clerk.

DESCRIPTION and METHOD of fixing the foundation of the second pier of *Perth Bridge*, according to the plan.

Method of fixing the coffer-dam.

THE gravel turning out harder than was expected in the last pier, and it taking up much time in driving the piles of the coffer-dam down to their proper depth, and also finding them very difficult to draw, and much shattered when drawn, I propose for this pier that as many additional piles be procured as will set the whole at the distance of 9 feet from sheeting of the base of the pier, and to drive them no farther than to fix them firm in the ground, which if that happens at 2 feet will be sufficient. The dam being then compleated to its proper height, in order to guard against filteration of the water under the bottom of the piles, I propose to throw in all round on the outside a quantity of gravel and corn mold earth mixed together, so as to lay rather sloping against the piles, and extending about 6 feet all round: the gravel being mixed with the earth, will not only augment its quantity, but prevent its being carried away by the stream, the use of the earth being to choak up the chinks and pores of the gravel upon the bed of the river. I apprehend about a cube yard of compound matter, to a yard running, thrown in, will be sufficient, observing to begin the work at the salient angle up stream, and proceeding gradually downwards on both sides, closing at the salient angle down stream.

Method of making the excavation.

The pumps being fixed, and the water pumped out, begin the excavation no larger than the base of the pier, and having got down a space in the middle to its proper depth, increase it in width and length till the area is clear for driving the piles upon which the foundation frame is intended to rest, and no more, leaving the matter on the outside of that area to form its own slope toward the coffer-dam, so that the rest of the area will be left solid, to support the sheeting of the dam; and if any part seems feeble, or likely to give way, let it be strengthened by driving piles for supporting slate on edge, as the nature of the ground and circumstances shall shew to be necessary, observing, in beginning the excavation, that the matter be thrown out all round, so as to secure and strengthen the matter first thrown on the outside of the dam.

The depth of the excavation will be found by the following rule. It must at least be excavated 3 feet at a medium below the natural surface of the gravel where the pier

ſtands; but if this does not carry down the baſe of this pier within 2 feet of the level, at which the baſe of the firſt pier was fixed, let the depth of the excavation be increaſed till it is within 2 feet of the former depth.

Method of fixing the foundation, according to the plan.

The excavation being made, as far as is above directed, let the 21 piles, upon which the frame reſts, be driven into their proper places: theſe piles are to be 10 inches heads, and of 6 feet long, ſuppoſing the gravel of equal ſtrength with the laſt, but if there is any reaſon to ſuppoſe it ſtronger or weaker, the length above mentioned ſhould be increaſed or diminiſhed This being done, and the pile heads reduced to a level, lay down the frame thereupon, which I ſuppoſe to be ready prepared in the yard, with the tye beams ready fitted with dovetails thereto, and being trenailed down upon the reſpective pile heads, proceed to drive the ſheeting piles, which may be of oak, elm, beech, or fir, as can beſt be got. I ſuppoſe them to be of 6 feet long; they may be driven plain, as ſhewn on one ſide, as was done at *Coldſtream Bridge*, but would be preferable if rebated, as ſhewn on the other half. The choice of the method depends on circumſtances; if, from experience of the other pier, they are like to drive regular, without tearing of the rebates, by meeting with great ſtones, &c. then they will both drive more regular, and hold firmeſt by being rebated, but if they are apt to ſplit, then it will be as well to ſave that time and labour, by making them plain, and more eſpecially ſo if the difference of expence in workmanſhip, or hindrance of time in doing it, is likely to be a material object, in that caſe the rebating may be omitted.

N. B. If driven plain, the breadths of the piles are not material; but if rebated, narrow piles will enhance the workmanſhip in preparing. In order to ſave timber (and eſpecially if fir piles are made uſe of, it will be much ſtronger) I propoſe to groove the piles on both ſides, and to nail in the tongue, which, if fir piles, may be of harder wood; the beſt proportion for fir piles would be to make the tongue $1\frac{1}{4}$ inch thick, and $1\frac{3}{4}$ broad, to be let $\frac{3}{4}$ into the ſide where it faſtens, and to ſtand out 1 inch; but this may be done according as the tools already prepared may ſuit, there being no need to make new ones on purpoſe.

The tops of the ſheeting piles being reduced to a level with the ſtring pieces (and ſpiked thereto as they are driven) the outſide muſt be reduced to a regular breadth, ſo as to take the notched ſtones in a line. This being done, the reſt of the bearing piles muſt be driven, beginning with the outſide rows, and cut to a level with the top of the

ſtring

ſtring pieces; theſe piles may be of 6 feet, more or leſs, according as the others are found to go.

The ſetting muſt be compleated by firſt underpinning the ſtring pieces and tye beams, as firmly and *equally* as they can, by moderately driving ſtones under them; and laſtly, the other ſpaces to be ſet, and well drove down as before; but before they are rammed down, the joints of the ſetting ſhould be filled by ſweeping in dry lime mixed with ſand and ſmall gravel, that when drove down the whole may be compact together.

When the pier is got above low water, I would have the matter taken out for 4 feet wide round the pier, down to the level of the top of the notch courſe, and filled with good lagging as before, ſtanding ſomewhat higher than the natural bed of the river, and the reſt of the ſpace covered with rubble to the ſides of the dam.

N. B. I ſuppoſe the bearing piles to be ſufficiently drove, when it takes 20 blows of a ſufficient ram to drive an inch, and the ſheeting piling to be ſo when it takes 40 blows to drive the ſame quantity; but the ſheeting piles ſhould be drove as near to a regular depth as poſſible.

J. SMEATON.

Auſthorpe, April 23, 1767.

P. S. I don't mean to ſet aſide the uſe of ſuch materials as were prepared according to the plan of laſt year, unleſs utterly inconſiſtent with the preſent.

PERTH BRIDGE.

Perth, October 5, 1787.

HAVING this day viewed the bridge of *Perth*, I have the ſatisfaction to obſerve every thing relative to it in perfect good condition, the walking path over it excepted; which, from the want of hardneſs in the ſtone wherewith it has been laid, is not only much worn, but from the hard pebbles imbodied in the ſtone itſelf is become very rough and uneven. For the effectual reſtoration of this part, nothing would be ſo compleatly durable, as to remove the preſent ſtone-work, and relay the ſame with *Aberdeen* granite of the ſame depth as the preſent. But as the preſent ſtone-work of the walking path appears to

to me to lay compleatly firm and ſolid, and being ſhewn a ſample of the *Kingudie* flat paving, which I underſtand can be procured of any thickneſs, with parallel ſurfaces, and alſo appearing to me to be of a nature ſufficiently durable, I apprehend the work may be executed in a ſubſtantial manner, as follows:

The ſtone from *Kingudie* being procured of 4, 5, or 6 inches thickneſs, as can be moſt conveniently had, and of ſuch lengths as to make good the whole breadth of the walking path without a joint, but of promiſcuous breadths in the direction of the bridge, I would adviſe to chiſſel or broach off the upper ſurface of the preſent walking path till it comes to a regular height, and then with good mortar to lay down the *Kingudie* flooring, cloſe jointed, upon it, making the joints of the flooring with the beſt *Pozzelana* mortar; and in caſe there is *Pozzelana* remaining in plenty, it would be well to give the mortar wherewith the flooring is bedded an allowance of *Pozzelana*, as ſuppoſe, half the quantity; obſerving to level the ſurface of the preſent maſs of ſtone in ſuch manner as to allow a drip or declivity from the parapet towards the carriage way of about $\frac{3}{4}$ of an inch; and alſo to make the breadth of the new flooring about $\frac{3}{4}$ of an inch ſhort of the preſent breadth, ſo that the tread of the carriages being taken off from rubbing againſt the *Kingudie* flooring, it may remain undiſturbed being defended by the ſolid of the preſent; and in the ſame way the walking path may be ſet with *Aberdeen* granite, provided it is worked to a parallel thickneſs.

With reſpect to the paving of the bridge, there is no objection to it as to the ſtructure, this being merely a matter of convenience, of which thoſe who from their local ſituations obſerve and uſe it can be the beſt judges. I have only to obſerve, that the *Aberdeen* granite paving is not only the moſt durable of any that I am acquainted with; but, from its roughneſs, the horſes feet are the moſt ſteady, and hold the firmeſt in drawing upon it. The blue whin is the next in degree; ſo that where the blue whin is procured upon the place, I cannot think it neceſſary to ſend for the *Aberdeen* granite from a diſtance.

Having viewed the bulwarks that have been erected oppoſite the *Inch* upon the north-eaſt ſide of the river, I am of opinion that all ſuch works as croſs and interſect the ſtream of the river, or interrupt the water from gliding freely away, are the means of increaſing the ſtreſs upon other parts, and therefore, as affecting other properties, ſhould be avoided. When properties want a defence againſt the incroachments of the waters, it ſhould be by diſpoſing thoſe defences at the foot of the banks, in a direction parallel to the ſtream, and without interrupting its free courſe.

J. Smeaton.

CHRISTCHURCH HARBOUR.

The REPORT of JOHN SMEATON, Engineer, upon the harbour of *Chriſtchurch* in *Hampſhire*, from a view thereof taken the 20th and 21ſt of May, 1762.

THE harbour of *Chriſtchurch* is ſituated in the bottom of a deep bay, formed between the iſles of *Wight* and *Purbeck*, and at the mouth of the two large united rivers *Avon* and *Stour*; the paſſage of which to ſea is between two natural points of land not much above 50 yards aſunder at low water, within which points the river forms a large inland bay or baſon, which is properly the harbour or haven of *Chriſtchurch*, and is defended from all winds: with thoſe outlines one would be naturally led to expect a good harbour, capable of receiving a number of large ſhips; yet, notwithſtanding theſe great advantages, nature has ordered it otherwiſe.

About a mile or better to the S. W. of the harbour's mouth begins an high point of land, called *Chriſtchurch Head* or *Heads*, for the coaſt, in running further to the S. W. forms another, which makes a double head, with a ſmall receſs or bay between; theſe heads, as well as a conſiderable part of the coaſt extending weſtward therefrom, ſtand bold upon the ſea, the foot thereof being waſhed by its waves at high water. Thoſe heads have formerly extended much further into the ſea than at preſent; but being compoſed of a looſe ſand, intermixed with ſome quantity of looſe iron ſtones, the action of the ſea upon the foot of theſe cliffs in time of ſtorms brings it down in great quantities, and is driven by the violence of the ſeas with wind from S. to S. W. into the bottom of the bay, and there being ſubject to no counteraction by the oppoſite winds, it has not only greatly obſtructed the bottom of the bay with ſand, but has ſpread itſelf to a conſiderable diſtance from the ſhore. It further ſeems to me that the harbour's mouth has formerly been much more extenſive than at preſent, having reached even to the heads; but the ſand gradually coming down from the cliffs, and being driven into the haven by the S. W. and S. E. winds, has gradually formed marſhes to the N. E. of the high lands, and thereby drove the mouth or channel of the river gradually to the N. E. and again, by the blowing of the ſand, left dry at low water, by the S. E. wind, it has formed a range of hommocks or ſand-hills, extending from the heads north-eaſtward to the ſouth point that now forms the harbour's mouth, and has thereby formed a natural bank, part of which ſeparates the baſon, now compoſing the harbour of *Chriſtchurch*, from the ſea. The ſands thus moving ſeem to have forced the mouth of the river as much to the

N. E.

N. E. as they well can be; and undoubtedly the whole had been long ago ſhut up, had it not been for the powerful re-action of the freſh waters continually preſſing toward the ſea from the two rivers aforeſaid, which, in wet ſeaſons, as they drain a vaſt track of country, muſt be very conſiderable; and indeed, by the power of ſuch a collection of freſh waters, great things might be done, did not nature throw out another rub in the way, and that is the ſmall flow of the tides at this place.

The great depth of this bay from the main channel tide, the ſhoalneſs of the waters occaſioned by the ſands beforementioned, and the diſtraction of the current in going different ways round the Iſle of *Wight*, I look upon to be the moſt probable cauſe of the ſmallneſs and irregularity of the tides here. It is not reckoned that the ſpring tides riſe more than from 5 to 7 feet, and the neap tides from 4 to 6; ſo that it ſometimes happens that the neap tides are higher than the ſprings, depending much upon the courſe of the winds; the tides are ſaid to be higheſt with a S. E. wind, and leaſt with wind at N.

I am alſo informed, that three hours after the regular time of high water, when the main tide in the channel begins to ſet towards the weſt, a ſecond tide is formed in this bay, which is generally higheſt at neap tides, and that the ebb between the two tides is from 8 or 9 inches to 18; which ſecond tide, proving a check of the reflowing power of the land waters, tends to weaken their force in getting to ſea.

From the circumſtances before deſcribed, viz. the flatneſs of the bottom, the conſtant motion and increaſe of the ſands, and ſmallneſs of the tides, I cannot flatter the inhabitants ever to expect an harbour at *Chriſtchurch* of any great depth or capacity; yet, at the ſame time, it ſeems to me capable of great improvement, as will appear from a further deſcription.

Between the points I found a conſiderable depth of water, but as the width of the channel greatly enlarges without the points, the depth diminiſhes, and at the diſtance of about 200 yards an hard gravel ſhoal is formed, and ſtill further out the bar. From the points to the bar the channel lays E. by S. and from the S. point there runs out a ſand, which is dry at low water, and extends from the ſaid point on the S. ſide of the the channel, and in a parallel direction thereto, as far as the bar. This view was taken on the ſecond and third days before the change of the moon, ſo that the ſpring tides were ſcarcely ſet in.

At this time I found 16 feet water between the points, 4 feet 9 inches upon the gravel ſhoal, and 5½ water upon the bar, and in the road, which lays about half a mile further

out in the same direction, 16 feet water; the bottom is said to be a strong blue clay, the *Needles* bearing S. E. by S. and *Christchurch Heads* S. W. and just open one with the other. Within the points the channel turns S. W. by the side of the hommacks before-mentioned, and from 16 feet, as it is between the points, comes to 7, 6, and 5 feet.

Christchurch Quay lies about two miles up the river from the harbour's mouth, between which there are the following shoals, beginning at the harbour, viz.

Friscum Shoal, water thereon 4 feet 9 inches, (when $5\frac{1}{2}$ at the bar as above) a loose gravel or shingle 2 feet deep, then turns harder. *Ganbury Shoal,* 5 feet water, bottom soft mud and sand. *Saltmard Corner,* $5\frac{1}{2}$ water, bottom loose gravel or shingle. The *Pick* had 6 feet 3 inches water, and a loose gravel or shingle bottom. There was no other place in the river but what sounded 6 feet or upwards at the said tide.

About 1 furlong from the S. point of the harbour's mouth, towards the S. W. is run out a kind of jetty or pier in a straight line, composed of round lumps of iron stone, which have been brought from the *Heads*; its direction is S. E. and extends from high water mark 256 yards; the *Needles* bear from thence S. E. by S. so that it is land-locked thereby a point of the compass; its top gradually declines from the shore towards the sea, the whole being uncovered at low water, but all or the greatest part covered at high water. Round the end of this pier I found about $7\frac{1}{2}$ feet water, and at about double this distance from the shore about 10 feet, (when $5\frac{1}{2}$ upon the bar) the water being rather better to the N. E. than to the S. W. of this line, the whole bottom being sand, and almost regularly inclining from the shore in the proportion abovementioned.

From information I learn, that the aforesaid pier or jetty was erected in the reign of King Charles the Second, and intended for securing a better passage into the harbour, and that for this purpose a cut was made through the hommacks, so as to let the water through the same out of the harbour, and so as to direct its course to the S. W. side of the pier.

This pier, it seems, was intended for the N. E. pier; another pier being designed on the S. W. side of the channel; the other passage in or near the present place was then stopped up with piles, &c. at a considerable expence: this course was maintained for some time, and a deep channel was made by the back waters alongside the pier of 15 or 16 feet deep; but then the matter being deposited, and the force of the land water being spent as soon as it quitted the end of the pier, there still must remain there a bar of the same height as the present bottom; however, as that bottom is at least 2

feet

feet lower than the present bar, it would make at least 2 feet more water into the harbour, which must, of course, prove a very great improvement so long as it lasted. But before a long time had passed it happened that the back waters, not finding a passage to sea sufficiently ready through this new channel, broke over, and forced themselves a fresh passage at the present place, which has ever since continued, and the artificial one was presently shut up by the sea.

From a due consideration of the facts and circumstances above recited, it appears to me as follows.

1st. That from the tendency of the land waters to open and preserve themselves a passage to sea at or near their present place, and from the tendency of the sea to shut up any passage made to the S. W. that the present course is best adapted by nature to be maintained: this is further confirmed by the bottom of the road, which, laying further out in the same direction, is clear of sand; but as the distances from the points to the bar, and from thence to a sufficient depth of water for an entry to a tolerable harbour, to which place two piers ought to be carried out to confine the land waters, and protect the channel from the driving in of the sand, in order to render the same effectual; I say, the great length required for such piers appears to me likely to be attended with too great an expence, added to the great trouble and difficulty in moving the gravel shoal before mentioned, otherwise, in my opinion, this construction would be the least exceptionable.

2d. It appears to me that the grand mistake in the former attempt consisted in constructing the wrong pier first; or in other words in making the channel on the wrong side of it: otherwise, for ought that to me appears, it might have maintained itself an open passage to this day; for had the S. W. pier been built first, or what amounts to the same thing, had this been made the S. W. pier, by making the passage on the N. E. side of it, then it would not have only defended the passage from the sands brought down from the S. W. by the action of the winds and storms from that quarter, but the sea, by breaking over the top of it, would have tended to have deepened the channel on the leeward side; whereas by making the channel on the windward side, it would tend to intercept the sands, and thereby immediately to fill up the channel, had not the superior force of the back water carried it out as fast as brought in; so that I rather marvel a passage was ever this way obtained, than that it should be filled up in the way it was managed.

That this must be the case in some measure, appears from the manner in which the sand now lays contiguous to the pier; for notwithstanding it is within 2 or 3 feet of the

top, yet it lays on the S. W. ſide at leaſt a foot higher than on the N. E. Indeed I cannot account for a conduct ſo abſurd, otherwiſe than by ſuppoſing the projector imagined the ſands to be immoveable, with reſpect to the winds and ſeas, and not in a travelling ſtate; and obſerving the ſtrong tendency of the channel to travel to the N. eaſtward, propoſed to ſtop it by interpoſing the pier. From this attempt however, though unſucceſsful, we may learn how ſtrongly the land waters acted, and what may be done by better management in the ſame ſituation.

The direction of the pier S. E. is very good, for veſſels may ſail in or out with a S. W. wind; it could not be pointed more ſoutherly, ſo as to give advantage to veſſels going in with wind nearer weſt, than they can now do, without giving advantage to the ſeas from S. S. E. to roll more directly in, as it would then not land-lock with the needles, but point to the open ſea; its ſituation is alſo very good, as it ſtands almoſt direct in a right line with a reach of the river, and if a veſſel ſhould not make the entrance of the harbour, they will have the road to the leeward.

I would therefore adviſe to conſtruct another pier parallel to the preſent one, but on the S. W. ſide thereof, and at the diſtance of about 240 feet from middle to middle; and when this is carried out from 50 to 100 feet further than the preſent pier, then to attempt to open a paſſage through the hommacks, ſo as to turn the water between them, and at the ſame time to divert the water from its preſent courſe at low water by a catch-dam of rough ſtones, or by a compoſition of piles, faſcines, ſtones, &c. by theſe means a ſufficient channel being procured between the two piers at low water, that channel will gradually deepen, and the preſent channel being deprived of the greateſt part of the reflowing power, the ſands that are now kept out by the ſame will begin to cloſe in, and in time will form hommacks ſo as make an entire ſtop at high water, and the progreſs thereof, as occaſion may ſhew neceſſary, may be helped by art.

By theſe means the earlieſt advantage may be taken of the undertaking, and veſſels drawing 8 feet water may be brought in at a midling ſpring tide; and as I would adviſe the whole to be performed by throwing in of ſtones upon the ſame principles as the preſent pier has been built, the piers may be gradually lengthened, conſtantly advancing the S. W. pier before the N. E. and it appears, that by extending the piers to double the length of the preſent, that is, to the length of about 500 feet, there will be $2\frac{1}{2}$ feet more water, that is, there will then at mean ſpring tide be $10\frac{1}{2}$ feet water, and at neap tides $9\frac{1}{2}$ feet, which will make a very good harbour for ſmall merchant ſhips, coaſting veſſels, armed cutters, &c. And as it appears that an extenſion of about 250 feet pro-

cures

cures $2\frac{1}{2}$ feet water, it follows that every 100 feet extent of the piers will procure an additional foot of water, fo that the improvement of this harbour may be carried on to any extent, by gradually lengthening its piers, as time, circumftances, the utility of the harbour, and ability to execute, fhall fuggeft.

I do not think it neceffary to do any thing to the prefent pier, till the weft pier is carried out as directed, and the water let in between them; but I would advife the weft pier never to be left till it has got above high-water. It muft at firft be made confiderably higher than high water, for as I would not advife attempting to dig away the fand for a foundation, whenever the current is turned againft it, it will fettle very confiderably, and unlefs a good body of ftone is originally laid, may fettle fo much as to make it difficult to add to the mafs at top. It is for this reafon I would not advife to make the prefent pier the weft pier, for having had a deep channel on the weft fide of it, the matter thereof on that fide had got fufficiently compacted to a due depth; but was the channel made on the eaft fide, the foundation being there fhallow, would be undermined, and occafion it to fettle afrefh, and require a large addition of materials to make it up to the fame height.

As the tides are faid to rife from 4 to 7 feet upon the bar, $5\frac{1}{2}$ will be the mean, which was what I obferved; and as I found no part of the river between the harbour and the town of *Chriftchurch*, but what, at that time, founded 6 feet and upwards, except the fhoals before fpecified, all which are compofed of foft and loofe matter, and of no great extent, I look upon it as very practicable, by dredging, to make good a 6 feet channel from the harbour to the town quay, at a mean tide, which will be very fufficient for all kinds of lighters and fmall craft. This may poffibly be done by the river itfelf, whenever it gets a more fufficient outlet to fea; and much more cannot be expected, without a very confiderable expence.

The iron ftones now laying upon the fands under *Chriftchurch Heads*, are a very proper material for the conftruction of the works abovementioned; but I fear they will not be found in fufficient quantities, if not, rough unformed ftones may be brought from *Peveral Point*, or *Portland*, the cap of which is refufe, and will anfwer as well as fineft ftone.

I have added a fketch of the harbour, as it appeared to me on view, and the meafures above fpecified, wherein what is done in red is the propofed works.

As this is a work that depends much upon circumſtances, it is not eaſy to make a tolerable eſtimate; yet, to give all the ſatisfaction in my power, the beſt I can judge of it is as follows.

ESTIMATE for the works propoſed to be conſtructed at the harbour's mouth, according to the preceding ſcheme.

	£.	s.	d.
I ſuppoſe the great S. W. pier will, at a medium, take 224 cube feet of matter in each foot running, and for 1500 feet 336,000 feet; this, allowing 12 feet of iron ſtone to the ton, will produce 28,000 tons; and ſuppoſing this to be brought from the heads, and laid in place at 2 *s.* per ton, will come to - - - - - -	2800	0	0
For the prolongation of the north-eaſtern pier 210 yards, I ſuppoſe 168 cube feet per foot running may be ſufficient, and this for 630 feet is 105,840 cube feet, which will make 8820 tons, at 2 *s.* - - - - - - -	882	0	0
For making a cut through the hommocks, at a medium, 66 yards long, 66 yards wide, and 3 yards deep, will contain 13,068 cube yards, which at 4*d.* comes to 217 *l.* 16 *s.* but as ſome work will be required in clearing away ſome of the ſand between the piers, till a paſſage can be procured, if for this ſervice we reckon 82 *l.* 4 *s.* the whole will be -	300	0	0
For covering the border of the new cut with ſtones, ſo as to prevent its waſhing, and thereby to prevent the water from getting part behind the piers; this, at a medium, being faced up half a yard thick, will take about 1500 tons, at 2 *s.* - - -	150	0	0
For making a catch-dam to force the water of the haven through the new cut and between the piers, at low water; this, if conſtructed wholly with rubble, and being ſuppoſed, at a medium, to contain 70 feet cube per foot running, this, for 720 feet in length, will require 4200 tons, at 2 *s.* - - - - - - -	420	0	0
To incidental expences, at 10 per cent. - - - - - -	455	0	0
	5007	0	0

N. B. As the quantities are given, if the iron ſtone can be moved cheaper than above ſet down, the ſaving will be in proportion; but if the quantity above ſpecified cannot be got from the heads, what will be neceſſary to be brought from *Purbeck* or *Portland* will be at an advanced price, and will at leaſt, I ſuppoſe, come to 5 *s.* per ton; but it is to be noted, that one ton of this ſtone makes 16 feet.

Auſthorpe, Auguſt 13th, 1764. J. SMEATON.

ADLING

ADLING FLEET LEVEL.

The REPORT of JOHN SMEATON, Engineer, upon a view and obſervation taken of the level of *Adling Fleet*, &c. from a plan of the ſaid level, taken by Mr. CHARLES TATE, Surveyor, in the year 1764.

IN the year 1755 I was employed by the owners of the manor of *Haldenby* to take a general view of this level, in order to form a ſcheme for the drainage thereof; and finding that the great defect laid in the drains and out-fall clough, I made a report, ſhewing how theſe defects were to be remedied, to the general advantage of the whole, as well as *Haldenby* in particular, as will more fully appear by reference to the ſaid report, not ſuppoſing at that time that the proprietors would be willing to be at the charge of getting an act of Parliament, in order to enable them to make new drains in any more proper direction.

The preſent view and report being made at the general requeſt of the principal proprietors of the ſaid level, who not ſcrupling the expence of an act of Parliament, in caſe it ſhould be requiſite, I have taken a further and more minute, as well as unconfined, view of the whole; and though from hence it appears that a more eligible courſe of drainage offers itſelf than the old one formerly propoſed, yet it alſo appears, that had my former directions been put in effectual execution, the proprietors would have found no occaſion for a ſecond application, and would have reaped the benefit of the improvements during the intermediate time.—I alſo find the coincidence of the levels taken then, and now, ſurpriſingly great, conſidering the badneſs of the ſeaſon then, and that the greateſt part of the low grounds were then under water, there being but 2 inches difference between the fall from the low part of *Haldenby Common* (which is the loweſt land) and the floor of our fleet clough, as taken then and now, as will appear by compariſon of the former obſervations with the preſent; but as the latter obſervations were made under more favourable circumſtances, and with more accurate inſtruments, I ſhall chiefly rely upon my laſt obſervations, which are as follow.

	Ft.	In.
Riſe from low-water mark at the *Ouſe*, September 1764, to the floor of *Hackenſyke* or *Ouſefleet Clough*, - - - - - - - - - -	3	0½
Riſe from the floor of the *Clough* to the ſurface of the water in the drain at *Coat's Bridge*, -	4	9
Riſe of water from low-water mark at the *Ouſe* to *Coat's Bridge*, - - - - -	7	9½

Many parts of the bottom of *Hackenſyke Drain* are not more than 14 inches below the level of the ſurface of the water at *Coat's Bridge*.

Riſe

	Ft.	In.
Rise from low water at *Trent Fall* to the surface of the water in the drain at *Coat's Bridge*, -	9	5
Fall of the *Ouse* from *Hackensyke Clough* to *Trent Fall*, - - - - - -	1	7½
N. B. The rise of the different points of the land above the water at *Coat's Bridge*, is inserted in circles upon the map.		
From *Coat's Bridge*, for the run of the water through the drains, I allow to the stagnant water on *Haldenby Common* a rise of - - - - - - - - - -	0	2
N. B. The depth of this stagnant water was in general about 9 inches; from this stagnant water to *Green Bank*, the water along *Eastoft Drain* was in general stagnant; but the sum of the rise taken at different stoppages amounted to - - - - - - -	0	3
Rise from thence to the mean surface of the land near the head of the division drain, between *Eastoft* and *Whitgift*, on the north side of *Green Bank*, - - - - -	0	7
Rise from *Coat's Bridge* water to the general surface of the land on the north side of *Green Bank*,	1	0
Rise from the general surface of the lands on the north to the surface of the water in *Eastoft Drain*, south of *Green Bank*, which were upon a level with the lowest lands there, - -	1	2½
Rise from *Coat's Bridge* to the surface of the lowest lands in *Eastoft*, south of *Green Bank*, -	2	2½

Consequently,

	Ouse at *Hackensyke Clough*.		*Trent Fall.* Ft.	In.
The lowest lands in *Haldenby* above low-water mark at - -	7	2½	8	10
The lowest lands in *Eastoft* and *Whitgift Moors*, north of and contiguous to *Green Bank*, - - - - - -	8	9½	10	5
The lowest lands in *Eastoft*, south of *Green Bank*, - - -	10	0	11	7½

As I found no considerable quantity of water remaining upon the tract of country under consideration, except upon *Haldenby Common* and adjacent places, it follows from hence that, agreeable to my former observations, *Haldenby Common* is the lowest part thereof, and consequently what will drain this part, will, of course, drain all the rest; and since this part lays 4 feet 2 inches above the floor of *Hackensyke Clough*, it may be wondered why 9 inches water should remain thereon in a dry season; but as it also appears, that many parts of the bottom of *Hackensyke Drain* lay but 14 inches below the water of *Coat's Bridge*, it will of consequence be not more than 7 inches below the land surface of *Haldenby Common*; from which if we take 3 inches for the declivity of the water, to produce a sensible run to the place of obstruction, there will remain only 4 inches for the depth of water upon the bottom of the drain, which is so small a body that the water cannot be run off in the course of the summer, if it should prove showery; nor otherwise, till it is evaporated by the sun and winds, which are the only means by which this piece of ground can be drained, as things are now constituted.

I thought

I thought proper more particularly to remark this fact, becauſe it at once points out the cauſe and cure of the evils that attend the whole level.

That *Haldenby Common* admits of drainage by *Hackenſyke Clough*, even as it now ſtands, appears hence.

	Ft.	In.	Ft.	In.
The whole fall from the ſurface thereof to the *Clough* floor being - - - -			4	2
Suppoſe 6 inches thickneſs of water to go over the firſt floor, - -	0	6		
The ſurface of the water being reduced 2 feet within ſoil, makes a complete drainage,	2	0		
		Sum	2	6
Remains the declivity of the water's ſurface in the drains between *Haldenby Common* and the *Clough*,			1	8

The diſtance by the courſe of the drains, ſtraightened according to A B G H I e f, will be 3 miles 2 $\frac{1}{2}$ furlongs nearly, which is full 6 inches per mile, which is within the limits of a good drainage.

Hence it appears, beyond a doubt, that the whole level may be drained by *Hackenſyke Clough*, as it now ſtands, provided drains of proper depth and capacity were made correſpondent thereto; but as that *Clough* lays full 3 feet higher than low-water mark, it is capable of being laid ſo much lower, and the drains being proportionably deepened correſpondent to this lower ſituation: this would occaſion ſo conſiderable a deſcent, as to run off the waters of the greateſt downfalls as faſt as they came down, without danger of overflowing any of the lower grounds, which might ſometimes be the caſe, was the *Clough* continued at it's preſent height *.—Let us now ſee what fall will be obtained, upon a ſuppoſition that the *Clough* floor was lowered 3 feet.

	Ft.	In.	Ft.	In.
The whole fall from the ſouth end of the moors contiguous to *Green Bank*, to the preſent *Clough* floor, is - - - - - - - -			5	9
And the *Clough* floor being lowered 3 feet, would make, - - - - -			8	9
The diſtance by the courſe of the drains ſtraightened, according to the letters A B C D E F h, will be not quite, but near upon five miles; and ſuppoſing we allow a deſcent of 1 foot per mile, which is very ample and ſufficient for any purpoſes of drainage, the whole deſcent would be, - - -	5	0		
And allowing for the thickneſs of water going over the floor,	0	6		
Sum to be taken from the whole fall, - - - - - -			5	6
Remains the quantity that the water will be reduced within ſoil, at the moſt remote low places,			3	3

* *N. B.* This would be prevented by gates being erected, as mentioned in my former Report.

N. B. This is 1 foot 3 inches more than necessary, and will be more at all nearer distances, as further appears thus:

	Ft.	In.	Ft.	In.
The fall from *Haldenby Common* to the *Clough* floor, if laid 3 feet lower, will be - -			7	2
The descent for 3 miles $2\frac{1}{2}$ furlongs, at 1 foot per mile, will be -	3	$3\frac{1}{4}$		
The water over the floor, - - - - - -	0	6		
The sum deduct from the whole, - - - - - -			3	$9\frac{1}{4}$
And there remains for the reduction of the water within soil at *Haldenby Common*, - -			3	$4\frac{3}{4}$

Hence it appears, that was *Hackensyke Clough* floor laid lower by 3 feet, and the drains properly adapted thereto, that it would be as effectual as could be desired.

It next comes in place to enquire, whether new drains in a different direction, and to a different out-fall, may not be more eligible than the former; and from inspection of the country it appears, that the natural course of drainage tends from *Haldenby Common* towards *Trent Fall*, which is undoubtedly the lowest ground; and it also appears from the levels that there is a greater fall thither than to the *Ouse* at *Hackensyke*, by 1 foot $7\frac{1}{2}$ inches; it also appears by the plan, that the distance, according to the course of the new proposed drain, *a b c d e f g h*, is rather more than $5\frac{1}{4}$ miles, which is somewhat more than $\frac{1}{4}$ of a mile more than the former, which in this case is inconsiderable: if therefore the drainage to *Hackensyke Clough* is as compleat as can be required, when laid 3 feet lower than at present, it will be still more unexceptionable when laid at the same depth at *Trent Fall*, for as it will then lay 1 foot 8 inches above low-water mark, it will run a greater length of time at each tide, and therefore the drains, after making proper allowance for the difference of distance, may be of less width than would be required at *Hackensyke* to be of equal effect.

The falls will then stand as follows:

	Ft.	In.	Ft.	In.
From the surface of the moors north of *Green Bank*, to the floor of the sluice at *Trent Fall*, laid 3 feet below that now at *Hackensyke*, - - - - - -			8	9
Thickness of water over the floor, - - - - - -	0	6		
Fall of the water $5\frac{1}{4}$ miles, at 1 foot per mile, - - - - -	5	3		
The sum to be deducted from the whole, - - - - - - -			5	9
Leaves for the reduction of the water within soil at *Green Bank*, - - - -			3	0
Again. From the surface of the land of *Haldenby Common* to the floor of the sluice at *Trent Fall*,			7	2
Thickness of water over the floor, - - - - - -	0	6		
Fall of the water according the course *a b c d e f g*, $3\frac{1}{2}$ miles, at 1 foot per mile,	3	6		
The sum to be deducted from the whole, - - - - - - -			4	0
Remains the reduction of water within soil at the lowest part of *Haldenby Common*, - -			3	2

This

This reduction would drain even *Plumb Groves* and *Robinſon Deeps*, was it not adviſable to reſerve thoſe undrained for watering cattle, for which purpoſe it will alſo be neceſſary to have land-doors to the outfall clough or ſluice, to pen the water at dry ſeaſons, and alſo at ſome other places; but as thoſe will be private works it will be needleſs to inſiſt thereupon. The proper widths, depths and dimenſions of the drains and ſluice are contained in the following Eſtimate. The courſe relative to *Trent Fall* are coloured yellow, thoſe to *Hackenſyke* red.

This level is very well circumſtanced with reſpect to barrier banks. The only ones that appear neceſſary to be repaired, on account of the general undertaking, is the ſouth wing of *Green Bank* and *New Bank*, the particulars of which are contained in the Eſtimate. I find the marks left by the floods laſt winter, upon the ſouth ſide of the *Green Bank*, to be 3 feet 11 inches above the ſurface of the loweſt grounds there, that is, 6 feet 10 inches above the loweſt grounds of *Haldenby*; and as this body of water was brought hither by a general overflowing of the level of *Hatfield Chace*, occaſioned by the breaking of the banks of the river *Idle*, it would in conſequence have laid almoſt the whole tract now under conſideration under water, if it had failed. It therefore plainly appears that this bank ſhould not only be continued as a barrier, but ſtrengthened and prolonged, as ſpecified in the Eſtimate, for the ſafety of all the lands laying north thereof.

It comes now under conſideration how far the drainage of the land of *Eaſtoft* ſouth of *Green Bank*, into the drains propoſed for this level north of *Green Bank*, can be complied with, with ſafety to the latter: and I am of opinion it may be done with perfect ſafety, provided the communication through *Green Bank* be made by a tunnel not more than 10 inches ſquare, with a ſhuttle or ſtop ſluice thereupon; for had ſuch a tunnel been open and running during the flood of laſt winter, had alſo the drains and outfall clough, ſpecified in the following Eſtimate, been then made, I am of opinion it would have been carried off as faſt as it was uttered, without overflowing the level. But to take away all ſcruple, I would propoſe to lay the running of this tunnel under the following reſtrictions.

1ſt. It ſhall always be kept ſhut whenever the grounds to be drained thereby are overflowed by the waters from *Hatfield Chace*, or any other foreign waters, overtopping it's barrier banks, and to continue ſhut ſo long as the water thereupon has any communication with any ſuch foreign waters.

 2dly.

2dly. That it ſhall be kept ſhut at all other times, when the water in the mother drain riſes within 9 inches of the ſurface of the low part of *Haldenby Common*, or within 6 inches of the general ſurface of the lands laying north of *Green Bank*, which may be aſcertained by ſetting up ſtones or marks for that purpoſe.

The continuing of the barrier of this part of *Eaſtoft* beyond the limits ſpecified in the Eſtimate, the internal drains, erections, and maintenance of the tunnel of communication, I look upon to be private works, reſpecting this part of *Eaſtoft* Lordſhip, and therefore not comprized in the Eſtimate; and as this ſcheme propoſes nothing more than the carrying the mother drain to the boundary of each Lordſhip, ſo as to give the waters thereof a proper outfall, all other drains and internal works are conſidered as private works, and to be done at the particular expence of the reſpective proprietors.

ESTIMATE for a Drainage, by a new courſe, to *Trent Fall*. The floor of the ſluice to lay 3 feet lower than the floor of the preſent Clough at *Hackenſyke*, that is, about 1 foot 8 inches above low water at *Trent Fall*, the ſluice to be 10 feet water-way, the drain to be 10 feet bottom, to riſe from the Clough towards *Green Bank*, which will be at the rate of 10 inches per mile.

	£.	s.	d.
To digging the pit for the clough or ſluice, 19 feet deep, 35 feet mean width, and 100 feet mean length, containing 2463 cube yards, at 4*d*. - - -	41	1	0
To 94 yards in length, from the *Trent* to *a*, excluſive of the ſluice-pit, 15 feet deep, 10 feet bottom, 50 feet top, containing 4700 yards, at 3*d*. - - -	58	15	0
From thence to *b*, 387 yards, 12 feet deep, 10 feet bottom, 42 feet top, containing 13416 yards, at 3*d*. - - - - - - -	167	14	0
From thence to *Hoggard's Lane*, the end of *Long Dyke Bank*, at *c*, being in length 1150 yards, being 10 feet bottom, 36 feet 8 inches top, and at a medium 10 feet 3 inches deep, containing 30796 cube yards, at 3*d*. - - -	384	19	0
From thence through the riſing ground of *Adlingfleet*, by the ſide of *Long-Dyke Bank*, to *d*, length 550 yards, 10 feet bottom, 36 feet top, and mean depth 9 feet 7 inches, containing 13628 yards, at 3*d*. - - - - -	170	7	0
From thence to the north end of *Willow Bank*, *e*, 2550 yards long, 10 feet bottom, 29 feet mean width at top, and 8 feet 1 inch mean depth, containing 44989 yards, at 2½*d*. - - - - - - - - - - -	468	12	8½
From thence to *Green Bank*, by the letters *e f g h*, being in length 5496 yards, at a medium 8 feet bottom, 18½ feet top, and 5½ feet deep, containing 42234 yards, at 2*d*.	351	19	0
To making the branch drain, *k*, *h*, for communicating the waters of *Whitgift* low grounds with the main drain, being 690 yards long, 5 feet bottom, 13 feet top, and 4 feet deep, containing 2760 yards, at 1½*d*. - - - - - -	17	5	0
Carried forwards,	1660	12	8½

	£.	s.	d.
Brought forwards, -	1660	12	8½
To repairing and ſtrengthening *New Bank*, by way of a barrier, to defend the whole level againſt *Reedneſs Common*, ſo as to have 12 feet baſe, 4 feet top, and 4 feet high, containing 2500 yards in length, and in the whole 8889 yards, at 1½*d*. - -	55	11	1½
To repairing and heightening *Green Bank*, from the elbow ſouthward, with an addition of 2 yards per yard running at a medium, being 1260 yards long, containing 2520 yards, at 2*d*. - - - - - - - - - -	21	0	0
To extending *Green Bank* about 100 yards further ſouth, ſo as to render the ſame effectual, to be 12 feet ſeat, 4 feet top, and 4 feet high, containing 355 yards, at 1½*d*. -	2	4	4½
Spade work - -	£. 1739	8	

Building.

	£.	s.	d.
To building a new ſluice, of brick with ſtone facing, at *Trent Fall*, to be 10 feet clear water-way, including temporary dams, drainage of water, filling in the ground, and opening the ſluice - - - - - - - -	500	0	0
For a road bridge, of brick, at *Hoggard's Lane* - - - -	40	0	0
To a ditto at *Cow Paſture Lane* - - - - - - -	30	0	0
To a bridge for cattle, the middle of *Haldenby Common* - - -	15	0	0
To a road-bridge, at the road leading to *Whinſgate Bank* - - -	30	0	0
To a cattle-bridge, over the main drain, to communicate the two parts of *Ouſefleet Common*,	10	0	0
To a ditto, over the branch drain - - - - - -	5	0	0
Building - -	£. 630	0	0

Abſtract.

	£.	s.	d.
Spade work - - - - - - - -	1739	8	2½
Building - - - - - - - -	630	0	0
Superviſing and contingencies, at 10*l*. per cent. - - -	237	0	0
Total,	£. 2606	8	2½

The quantity of land uſed in this undertaking.

	Cut.			Covered.		
	A.	R.	P.	A.	R.	P.
In *Adlingfleet*, *Trentfield*, and high grounds from *Trent* to point *d*,	5	3	16	11	2	32
Adlingfleet low ground, from *d* to *e*, - - - - -	5	0	16	10	0	32
Willow Bank from *e* to *f*, there being ſpace enough for the cut	-	-	-	2	0	0
From 5 to *m*, acroſs *Haldenby Common* - - - -	2	1	16	4	2	32
Through *Ouſefleet Moor*, &c. from *m* to *b*, at *Green Bank*	4	0	0	8	0	0
The branch drain to *Whitgift Moor*, from *k* to *i*, - -	0	2	20	1	1	0
	[illegible]	[illegible]	[illegible]	37	3	16

Abstract of the Estimate by way of *Hackensyke*.

The drainage by *Hackensyke* being estimated in the same particular manner, and the main drain being made 11 feet bottom, to the point *B*, near *Coat's Bridge*, in order to be an equivalent to the greatest length of time of running at *Trent Fall*; and being made from thence in two branches, one along the course *C, D, E, F, b*, which will drain *Ousefleet*, *Whitgift*, and part of *Eastoft*, and the other by the course *B, G, H, I, e, f*, which will drain *Adlingfleet*, *Fockenby*, and *Haldenby*, and also a second branch from *C*, by the *Folly* to *Bought Gate*, to make a proper out-fall for *Eastoft* waters.

	£.	s.	d.
The Spade Work - - - - - - -	1833	4	10
Building - - - - - - - - - -	645	0	0
Contingencies, at 10 per cent. - - - - -	248	0	0
Total,	£. 2726	4	0

Land used in this Undertaking.

	Cut. A.	Cut. R.	Cut. P.	Covered. A.	Covered. R.	Covered. P.
From *Ouse* to *A*, - - - - - -	1	1	12	2	2	24
From *A* to *C*, - - - - -	8	0	35	16	1	30
From *C* to *Green Bank* - - - - -	3	1	20	6	3	0
From *B* to *e* - - - - -	2	1	20	4	3	0
Willow Bank, *e* to *f*, land enough for a cut, - - -	-	-		2	0	0
Branch from *C* to *Bought Gate* - - - - - -	1	0	0	2	0	0
	16	1	7	34	2	14

N. B. If *Hackensyke Clough* was made use of, as long as it will stand in it's present form, and the drains dug of a proper width to admit of their being carried to a proper depth, when that Clough shall be obliged to be rebuilt on account of repairs, and lowered to the proposed depth,

	£.	s.	d.
The Spade Work will then come to - - - - - - -	1691	3	10
The Building to - - - - - - - - -	145	0	0
Contingencies to - - - - - - - - -	183	12	0
	£. 2019	15	10

And in case *Ousefleet Clough* was to remain as it does, without intention of lowering the same, the expence of proper drains, &c. suitable thereto, would amount to 1636*l.* 5*s.* 0½*d.*

J. Smeaton.

Austhorpe, December 3, 1764.

DRIFFIELD BECK CANAL.

ESTIMATE for making a navigable Canal from *Driffield Beck* to a place called the *Townsend*, near *Skerne*, to be 16 feet at bottom, and 4 feet deep of water, with batters or slopes according to the nature of the ground.

	£.	s.	d.
FROM *Driffield Beck* to the beginning of *Lewcop* pasture, being 15½ chains length, mean depth 6 feet 5 inches, batters 1 to 1, the mean width at top will be 28 feet 9 inches, containing 5432 yards, at 2 *d.* - - - - - - -	45	5	6
Crofs *Lewcop* pasture to the low corner of the *Holmes*, length 12.3 chains, mean depth 8 feet, the batters as 3 to 3½, the mean width at top will be 34 feet 9 inches, the solid contents 6110 yards, at 3 *d.* - - - - - - - -	76	9	9
From the low corner of the *Holmes* to 19.6 chains up the same to the point 1 in the map, mean depth will be 11 feet 8½ inches, and being of a marly nature, the batters as 3 to 4, the mean width at top will be 47 feet 2 inches, the solid contents 17712 yards, which being hard to dig may come to 4 *d.* - - - - - - -	295	4	0
Cutting to the middle of the *Holmes*, - - - - - - -	416	19	3
To enlarging the canal to 28 feet bottom, for 60 yards at the head, so as to take 2 boats in breadth and 3 in length, for convenience of unloading at warehoufes, being there 12½ feet deep, - - - - - - - - - -	16	13	4
To drainage of water, fupervifing, and contingencies, - - - - -	60	0	0
To the middle of the *Holmes*, - - - - - - -	493	12	7

From the middle of the *Holmes*, to the *Townsend*, upon a dead level.

	£.	s.	d.
To carrying on the cut from the middle of the *Holmes* to the top of the *Pighill* at P, being being 31.10 chains long and 18 feet mean depth, the batters being 3 to 4, the top width will be 64 feet, the solid contents 54720 yards, at 4 *d.* ½. - - - - -	1026	0	0
From thence to the *Townsend*, being 23.5 chains length, mean depth 20 feet, the batter 3 to 4, the top width will be 72 feet, and the solid contents 53079 yards, at 5 *d.* - -	1105	16	3
	2131	16	3

ESTIMATE for carrying the navigation to the *Townsend* by a lock.

	£.	s.	d.
To the middle of the *Holmes*, the cut as before, - - - - -	416	19	3
A lock there to rife 10 feet, - - - - - - -	600	0	0
To cutting from thence to the top of *Pighill* 31.1 chains, at a medium 8 feet deep, batter 3 to 3½, the top width will be 34 feet 9 inches, the solid contents 15443 yards, at 3 *d.*	193	9	9
Carried over	1210	9	0

	£.	s.	d.
Brought forwards	1210	9	0
To cutting from top of *Pighill* to *Townsend*, being 23.5 chains, mean depth 11 feet, batters as 3 to 4, the width at top will be 45 feet 4 inches, the solid contents 19399 yards, at 3*d.* ½	282	18	0
To making the dock as before, - - - - - - -	16	13	4
To bringing the water over the moor, suppose - - - -	15	0	0
To supervisal and contingencies, - - - - - - -	150	0	0
Total	1675	0	4

A DESCRIPTION of this plan, with a comparative calculation of its abilities with the present work, here follows:

1, 1, 1, &c. represent the different parts of the frame-work, 2, 2, 2, &c. the parts of the water-wheel; 3, 3 its starts, of which more hereafter; 4 the main shafts ends; 5, 5 the parts of the spur-wheel; 6 the wallowers; 7 the crank; 8 the crank rod, which communicates with the sub regulator; 9 and 10 the communicating rod between; 9 the sub, and 11 the top regulator; 12, 12 the arch heads to the top regulator, to enable the buckets to make a perpendicular stroke, thereby enabling them to last much longer, go looser leathered, which will chamber or wear the barrels less, and lose less water. B. B. The chains to the bucket or piston rods; 14, 14 the bucket rods; 15 the bucket at the end of its rod in the section of the engine; 16, 16 and 17, 17 the face view of an engine together.

Now whereas the circumstances attending these works, being almost peculiar to themselves, it requires, in order to render them more efficacious and serviceable, a particular or peculiar application; for though there are many stream and current mills, yet they go with a much more uniform motion, having nearly a certain quantity of back water, or strength of current; but as both these articles are so varying at these works, it requires a varying application of machinery, which is performed as follows: supposing the wheel to be at work with the greatest strength of tide, and going three turns per minute, then the sub regular to 9 has its fulcrum or center of motion at *a*, which being 12 feet distance from *b*, where the crank rod lifts 2 feet 6 inches, and *b* being 6 feet from *c* in the sub, and *d* in the top regulator, both lift 2 feet 9 inches; and as *d* is 10 feet distant from its center of motion *e*, and 3 feet from *f*, the chains center, and that of the barrel, therefore it makes 4 10½ stroke in the barrel; and when the wheels are at work with a great quantity of water, and move at a flow rate, yet there is the sufficient momentum or force

force to raiſe much water; that force being always as the quantity of water multiplied into the velocity, ſo that if there be three times the depth in water, and but one third of the velocity, that is, at the ſtrength of the tide, nearly as much water may be raiſed as at ſtrength of tide, in order to attain which, it is neceſſary the engines ſhould make a ſtroke proportionably longer, as they move fewer times, which will be obtained by moving the center of motion *a* to *a a*, then as *a a* will be 5 feet 6 inches from *b*, upon the crank-rod lifts 2 feet 6 inches, and *b* being 6 feet from *c*, therefore *c* and *d* in the top regulator are both lifted 5 feet $2\frac{3}{4}$ inches, and *f* the chain, and, conſequently, the rod 6 feet $10\frac{1}{2}$, which is ſuch a ſtroke made in the engine, which compenſates in a great meaſure for the ſlowneſs of motion in the wheel; and all this is done in the moſt ſimple and laſting manner, by the application *g* at the end of the ſub-regulator 9.

Now the comparative quantity of water raiſed by the preſent, and what might be raiſed, are as follows.

Having conſidered that though there are rules in mechanics for finding the quantity of water paſſing by in a given time, in a given ſection, by knowing the height of the water, but as that is very difficult but where the back water is very inconſiderable, and that the velocity of the water at its ſurface might be obtained, I rejected both in this caſe, and noted, that the three-ring wheel, at the ſtrongeſt working, has gone $6\frac{2}{3}$ turns per minute, which is nearly 25 feet diameter, and the new wheel in the ſame time made $5\frac{1}{2}$ turns per minute, which is nearly 30 feet diameter; the whole ſpace paſſed through in the minute, by each wheel, being 495 feet, this, with their charge of work on them, which muſt impede the water's motion at leaſt $\frac{1}{4}$; therefore, if neither had been doing work, the water, by going $\frac{1}{4}$ quicker, would have paſſed through a ſpace of 619 feet per minute, which multiplied into 5 feet, which is about the depth the wheels go the ſtrongeſt at, and the product in 12 feet from the width, gives 37140 cubic feet of water expended on the wheel per minute, which is 3612 hogſheads; now as the wheels revolution vary as $6\frac{2}{3}$ to $5\frac{1}{2}$, therefore the quantities raiſed muſt vary in like proportion, that I will reaſon upon the greateſt quantities raiſed, which is $15\frac{1}{2}$ hogſheads per minute. Now as the difference or head of water is obtained by knowing the water's velocity, and that being known as above to be 619 feet per minute, it reſults that the acting head to produce that muſt be 2 feet nearly; and I will ſuppoſe that the average height of all the water then raiſed by the four engines on the wheel did amount to 100 feet, that is what ſome part of it might be raiſed higher, other like part diſcharged as much lower, and as 2 feet, the acting head, is contained five times in the height, we will ſuppoſe each hogſhead to be one pound; then ſuppoſe 3612lb. (or hogſheads) expended on the

wheel each minute, to be laid upon one end of a lever at 1 foot diſtance from the center, it is evident it would keep in equilibrio 72 lb. at the other end, which is ſuppoſed to be 50 lb. on the other ſide of the center, which 72 ſhould be the number of hogſheads of water the wheel ſhould keep ſuſpended on the engines, it being the 50th part of the water expended, and fluids act in reſiſting in this kind as ſolids, on levers; but to allow amply for friction, &c. and to give the part of the machine ſufficient motion, I will ſuppoſe, that nearly $\frac{1}{3}$ of the 72 might be raiſed, (for in good machines, under favourable circumſtances, $\frac{3}{4}$ of the 72, or 54 hogſheads, might be raiſed) which will be 24, and, according to my expectation, ſomething more than that quantity, viz. 27 hogſheads per minute, for and by the following reaſons: as the wheels floats are now no more than from 15 to 24 inches wide, they can produce no greater effect by their reſiſtance than in proportion to their ſurface, for all the water that might be acting againſt them, extra to their preſent dimenſions, goes over, rather to the impediment of the wheel than not, whereas was this width increaſed, the power of the wheel would be increaſed likewiſe to a certain meaſure, but not if the other parts remained the ſame as now, for as the wheels go now nearly the ſame pace as the water, therefore it is neceſſary to ſlacken the wheels motion, and increaſe the engines ſtrokes, to reſiſt the running water more, and thereby a proportionably greater quantity of water would be raiſed: then the ſtarts 3.3, ſhould be thus conſtructed; they ſhould all ſtand out 3 feet from the ring, each other having the boards only up to the ring, as may be ſeen by inſpection, and the others having the boards within to 5 feet from the ſtarts end, as ſhewn: the method for doing them cheapeſt, moſt laſting, and ſerviceable, is to make the ſtarts pretty wide, cut a ſlit in the middle, and ſlip the boards down it, and the whole is ſecured with a ſmall bolt in the ſhort, and two in the long ones, without iron plates; and up againſt each arm of the water-wheel to put boards 6 feet from the ſtarts end, by this method the wheel will be impeded getting into water leſs than if the ſtarts were all 5 feet long, and the boards as broad, and nearly the ſame effect produced.

Now by this proviſion, the wheel, when going ſo ſlow as 3 turns per minute, will ſo reſiſt the water as to give it an opportunity to act ſo powerfully as to work 6 engines of ſeven-inch barrels in this manner at ſtrength of tide, 3 turns the wheel, the wallowers going 3 to the wheels 1 makes 9, and the ſub-regulator moving on the center *a*, will produce 4 feet $10\frac{1}{2}$ inches ſtroke, which multiplied into the 24 barrels will produce 27 hogſheads nearly per minute; and in leſs ſtrength of tide, for ſome time before and after high water, the wheels will go from 1 to 2 turns per minute, by means of the large ſurface of floats, I will call it $1\frac{1}{2}$ turns, and then the ſub-regulator will move on the center

center *a a*, which will produce 6 feet $10\frac{1}{2}$ inches ſtroke in the engine barrels, and that in the 24 barrels will give 19 hogſheads per minute.

3 rings at $6\frac{3}{4}$ turns riſe 15 hogſheads per minute.	This deſign at 3 turns to riſe with 4 feet $10\frac{1}{2}$ inches ſtroke, 27 hogſheads per minute.	Ditto at $1\frac{1}{2}$ 6 feet $10\frac{1}{2}$ inches ſtroke, 19 hogſheads per minute.

The following is an examination of the ſaid engine, in anſwer to the above.

Examination by JOHN SMEATON of a deſign for a Water-Engine, communicated by Dr. BIRCH.

This deſign, though not ſo mentioned, appears evidently intended for *London Bridge* water-works, and therefore as ſuch I ſhall conſider it; and though the unknown inventor of the deſign has ſhewn evident marks of genius, and a laudable attempt of improvement, yet as I cannot agree with him in the whole of his reaſoning about it, I think it neceſſary to give my opinion with that freedom that becomes me in a matter wherein I am conſulted, and therefore have a right to expect that what I may ſay will not be conſidered as the effects of a deſire to criticiſe, but to do juſtice, where my opinion is deſired in the way of my profeſſion.

In the firſt place, I agree with the inventor in the uſe of arches and chains at the end of the regulator, having ordered the like in the engine lately erected for the *Weſt Ham* Company at *Stratford*.

2d. I alſo agree with him in thinking the circumſtances of theſe works are ſo peculiar to themſelves as to require peculiar applications, in order to bring them to perfection, and that it is to be wiſhed that means could be found out by which the load could be occaſionally varied, in proportion to the variations of velocity and power, without rendering the engines complex, and more liable to be out of order. I alſo agree with him, that by means of a moveable center, to what he calls a ſub-regulator, the ſtroke of the engine may be varied, and therefore the power of the engine in the ſame proportion; but I can by no means agree with him in the uſe to be made of this machinery; he ſuppoſes that when the tide is high, and the current moves ſlow, that the body of water being then great, the ſuperior quantity will be equivalent to the want of velocity, ſo that if there be 3 times the depth in water, and but $\frac{1}{3}$ of the velocity, that is at the ſtrength of tide, nearly as much water may there be raiſed; as at the ſtrength of tide.

 But

But had the inventor computed the head or acting column of water neceſſary to produce $\frac{1}{3}$ of the velocity, by the ſame rules that he finds 2 feet neceſſary to produce the velocity of 619 feet per minute, he would have found $\frac{1}{3}$ of 619, viz. 206 feet per minute, produceable by a head or column $2\frac{2}{3}$ inches, which is only $\frac{1}{9}$ of 2 feet, it being well known that the ſquare of the head is as the velocity. Hence it appears, that as the acting column is only $\frac{1}{9}$ of the height, the impulſe or preſſure upon the ſame quantity of ſurface of float-board will be $\frac{1}{9}$ alſo; and even if we ſuppoſe the ſurface acted upon to be increaſed in proportion to the depth of water, which is not the caſe, (in the conſtruction before me) the whole impuſe or preſſure upon the wheel can be only $\frac{1}{3}$ of what it would be at ſtrength of tide; ſo that if the wheel is loaded as here propoſed, near high water more than at ſtrength of tide, in the proportion of 4 feet $10\frac{1}{2}$ inches to 6 feet $10\frac{1}{2}$ inches, which is as 5 to 7 nearly, it is very probable that the wheel, inſtead of doing *nearly as much as at the ſtrength of tide*, would ſtand quite ſtill, and the benefit of the ſlow motion, that would otherwiſe take place, quite loſt: in ſhort, it is like a horſe moving ſlow with his load in conſequence of having carried it far, and being wearied therewith, to load him harder in order that the greater burthen may compenſate for the ſlowneſs of his motion. It therefore plainly appears, that if any good is to be expected from this ſliding motion, it muſt be by adjuſting the longeſt ſtroke to the ſtrength of tide, that as the tide grows weaker the ſtroke may be ſhortened, and the power of the engine adapted to the power to move it.

In regard to the machinery of the ſliding center, as it is not perfectly made out, I am enabled to ſay the leſs upon it; but in an engine that works both ways, that is, lifts up as much as it pulls down, any ſhake in the center work will be very detrimental to its motion, and occaſion it to be frequently out of order; and further I conceive it difficult ſo to contrive it as to be, and keep laſtingly ſteady, eſpecially as in the preſent engine, in ſome caſes, the action of the crank upon the center will be greater than its action upon the piſton, as 11 to 4; but ſuppoſing the difficulties in the execution to be conquered, ſtill this muſt happen, that as the barrels in moderate ſpace of time will ſenſibly chamber, and the middle part of the barrel, ſo far as the ſhort ſtroke reaches, will be always in wear, but that part above and below the limits of the ſhort ſtrokes only in wear when the long ſtroke is uſed, it follows that the barrels will chamber unequally. An engine will go very well with its barrel a good deal chambered; in ſhort, they are ſeldom rebored ſo long as a new leathered piſton can be got in at the mouth ſo as to fill in the chambered part, but then as they chamber nearly equal, and the ſtroke remains the ſame, that of the barrel in which the piſton moves is ſtill nearly a cylinder; but, in the caſe of unequal ſtrokes, the piſton would be obliged to move through a ſpace alternately narrower and wider, which would cauſe it to work very hard.

Again,

Again, as it might be ſometimes for ſome days together in neap tides that the long ſtroke would not be made uſe of, the extra parts in that time would in iron barrels grow ruſty, and when uſed again would not only cauſe the engine to go ſtill harder, but alſo deſtroy the leathers. This laſt inconvenience would indeed be remedied by braſs barrels; but where the charge and difficulty is great, and the effect not greatly ſuperior, an invention ſo circumſtanced is leſs eligible. This thought of altering an engine's power by a different length of ſtroke is not new to me, having had the ſame thought ten years ago; but while I was contriving the machinery neceſſary to perform it, the objection of the unequal chambering of the barrels occurred to me, which made me lay it aſide, though caſes have occurred to me in which it would otherwiſe have been applicable and uſeful.

It now comes in place to enquire into the general proportions and adjuſtments of the engine, to work at ſtrength of tide; and I agree with the inventor, that a wheel of large diameter will wade in a great depth of water to more advantage than a moderate one; that a great breadth of float-board will reſiſt the current more than a narrow one, and, conſequently, give more power to the engine; and that the wheels, at ſtrength of tide, may, with advantage, be made to move with a greater load than they do at preſent, but advantages carried to extremes often prove diſadvantageous, according to the proverb, things in a middling way are frequently beſt.

With reſpect to the water wheel's height, that a wheel of 30 feet will get better through the water when wading at a given depth than one of 30 or 25 feet, is already allowed; but then as it moves proportionably ſlower, what is loſt in number of revolutions of the firſt mover (in order that the ſame quantity of water may be raiſed) muſt be gained in the ſecond; ſo that the ſame ſpur wheel will act on a leſs wallower, or a larger ſpur wheel acting upon the ſame wallower, produces a proportionably greater ſtrain or twiſt upon the axis of the water-wheel; again, if more engines are put on, or with longer ſtrokes, or both, the ſtrain will be greater in proportion to the increaſe of water drawn thereby; if, therefore, the 25 feet wheel's axis goes $6\frac{2}{7}$ turns for the propoſed wheel's 3, the ſtrain upon the old axis to that of the new will be as 3 to $6\frac{2}{7}$, ſuppoſing the ſame work done by both; but if the work done is more in the proportion of 15 to 27, the number of hogſheads ſuppoſed to be raiſed by each, or, as I calculated it, 13,2 to 26,7, the compound proportion will be 39,6 to 17,8, that is, the ſtrain or twiſt upon the new wheel's axis, when at its leſſer ſtroke, will be $4\frac{1}{2}$ times greater than that of the preſent 25 feet wheel; ſo that it is much to be queſtioned, whether an axis of 3 feet diameter, (which I apprehend to be that here propoſed) or indeed any timber that can be got, will bear the ſtrain ſo as to be ſufficiently laſting.

The

The ſize, diſpoſition, and machinery of the floats I think is very good, but I think a ſmaller number would do as well in this ſituation: as to the fall propoſed to the breaſt of the wheel, I think it not only expenſive and difficult here to lay, but uſeleſs in this place on tide of ebb, and detrimental to the action of the wheel on tide of flood. The propoſition of increaſing the number of barrels I can by no means approve, for either another crank muſt be added, or there muſt be ſix barrels to each engine, either of which will be attended with inconveniencies, more complication, and more increaſe of friction than is neceſſary.

Laſtly, with reſpect to the compariſon of the effects of the old and new engine, I look upon it as a matter of certainty, from obſervation, that the 25 feet wheel moves $6\frac{1}{3}$ revolutions at ſtrength of tide, and, therefore, that its mean circumference moves through a ſpace of 495, or, as I make it, of 497 feet, and, in this caſe, bona fide raiſes 13 hogſheads of 63 ale gallons each per minute; but what is the velocity of the water driving the wheel, by no means appears, we are ſure the natural velocity of the water muſt be greater than the wheel, but whether it be $\frac{1}{8}$, $\frac{1}{6}$, $\frac{1}{4}$, $\frac{1}{3}$, or $\frac{1}{2}$, by no means appears; the number 619 therefore, expreſſing the velocity of the water per minute, cannot be conſidered otherwiſe than as conjectural, and, conſequently, the number 3612 hogſheads expended per minute, deduced therefrom, muſt be conjectural alſo: the acting head to produce 619 feet velocity is 1 foot 8 inches nearly, not two feet as here ſuppoſed; but if 619 is conjectural, the head 1 foot 8 inches muſt be alſo conjectural.

The mean height to which the water was ſuppoſed to be raiſed, viz. 100 feet, I apprehend is alſo conjectural, ſince it riſes higher or lower in the ſtand-pipe, as there are a greater or leſs number of cocks open upon the mains: now if 100 be divided by 1 foot 8 inches, the quotient is 60; but as both the diviſor and dividend are conjectural, the quotient will be ſtill more ſo, and this being again a diviſor to the conjectural number 3612, the quotient, which will be 60, will be ſtill more conjectural; but ſuppoſing the number 619 and 100 both right, or nearly ſo, then the number of hogſheads equivalent to the power will be 60, but ſtill there remains a difficulty what proportion of this quantity we muſt take for the neat performance of the engine; few or no engines that I have ſeen have yielded $\frac{3}{4}$, moſt fall ſhort of $\frac{1}{2}$, and the preſent engine leſs than $\frac{1}{3}$, but more than $\frac{1}{5}$, that is, in caſe we are right in the two numbers before-mentioned, becauſe if we are not, we ſtill remain uncertain what the effect thereof is, in proportion to the power producing it. All, therefore, that we can fairly conclude is this, that a greater quantity of float-board will give a greater power, and a greater capacity of pumps will raiſe a greater quantity of water, provided we do not overload our power, or break our tackles by overſtraining.

GASCOIGNE.

GASCOIGNE on RAISING WATER out of SHIPS.

EXAMINATION of Mr. GASCOIGNE's propofals for raifing water out of Ships. By JOHN SMEATON.

RESPECTING that part of his propofal which confifts in applying the forcing pumps to the raifing of water out of the hold of a fhip, by which means he is enabled to place the moft effential parts of his machinery below the water line, is a merit that will be obvious to every feaman; I fhall therefore not take up time in faying more about it than that it feems worth attending to, in cafe the conveniency of a fhip will admit its execution, and the more efpecially as I am very certain, from experience, that as much water may be raifed in this way as any other. But in regard to the great preference Mr. GASCOIGNE gives his pump above the chain pumps, in point of quantity delivered, and in point of power wherewith he propofes to work it, I can by no means agree with him. He propofes to raife 86 tons of water per hour to the height of 22 feet, by four men; whereas he gives us to underftand, that the common chain-pump requires 14 men to raife 60 tons per hour to the fame height; a very furprifing difference indeed! In order to prove this, he has recourfe to calculation, and, as a ground-work, make this *fuppofition*, that four men will turn round the winch or handle of his machine 60 turns per minute, in which cafe, as this will produce a ftroke of 1 foot long in four pump-barrels of 6 inches diameter each, this will neceffarily produce a certain quantity of water per hour, which he calls 86 tons, but which, according to my computation, (fuppofing none loft) is fcarcely 84; but this I pafs over: now if, on the other hand, we fuppofe that four men *cannot* turn round the winch 60 turns per minute, then the whole computation falls to the ground. He endeavours further to fupport himfelf by a comparifon of the friction of his engine with the chain-pump; in order to this, he calculates the number of frictions in his machine, and gives each of them a determinate value, viz. four pounds; he alfo calculates the number of frictions in the chain-pump, and calls each of *them* five pounds; but as this is a method of computation totally new to me, and as he has given no fufficient reafon why he calls a friction in one machine four pounds, and in the other five, nor why he might not as well have called them four ounces each, or 40 pounds, as beft ferved his purpofe, I fhall not take up any more time in purfuing him any farther in this road, but fhall endeavour to fet the whole in clear light.

Desaguliers, in the ſecond volume of his Experimental Philoſophy, has taken a good deal of pains in finding out a kind of land-marks to guide us in thoſe kinds of purſuits, and to enable us to value the pretenſions of projectors in the art of raiſing water; and he has told us, that the mean ſtrength of a man, when applied to the beſt kind of pump that has been yet in uſe, amounts to no more than the raiſing one hogſhead of water in a minute to the height of 10 feet; for my own part, I have made a variety of machines and many obſervations of this kind, but never yet found the value of mens ſtrength at a medium equal to what is ſet down by Desaguliers, unleſs they are ſuppoſed to work in haſte, or diſtreſs, for a few minutes; however, as it is more favourable to Mr. Gascoigne's propoſal, we will for the preſent ſuppoſe the performance of men equal to what is ſtated by Desaguliers, viz. one hogſhead per minute at 10 feet high, that is, at the rate of 60 hogſheads per hour.

Now by the unalterable laws of hydroſtaticks and mechanicks, if a man can only raiſe 60 hogſheads 10 feet high per hour, he can only raiſe 30 hogſheads to 20 feet, and only $27\frac{3}{11}$ hogſheads to 22 feet in an hour, by the ſame rule of proportion. Now $27\frac{3}{11}$ hogſheads, conſiſting of 54 ale gallons, as ſuppoſed by Desaguliers, makes $7\frac{1}{8}$ tons nearly, that can be raiſed by one man per hour, to the height of 22 feet, and conſequently that $28\frac{1}{2}$ tons per hour is the utmoſt that can be raiſed by 4 men, inſtead of which Mr. Gascoigne propoſes to raiſe 86.

If we examine what he has ſtated concerning the chain-pump, by the ſame rule, we ſhall find its pretenſions more modeſt: he ſuppoſes the chain-pump to raiſe 60 tons per hour by 14 men; now if $7\frac{1}{8}$ tons per hour is all that can be raiſed by one man to the height of 22 feet, 14 times $7\frac{1}{8}$ tons equal to $99\frac{3}{4}$, or in round numbers 100 tons, is the utmoſt that can be raiſed by 14 men, inſtead of which the chain-pump only raiſes 60; ſo that here it falls conſiderably ſhort of the mark. However, we may hence conclude, that as the chain-pump is deficient only 40 parts in 100, that all the pump-work that can be contrived will never exceed the preſent chain-pumps above the proportion of 60 to 100; whereas, men and quantity conſidered together, Mr. Gascoigne propoſes to improve upon the chain-pumps in the proportion of 60 to 301, which is the number of tons that ought to be raiſed by 14 men, according to Mr. Gascoigne's method. For my own part, I believe that the friction naturally attending the chain-pump will never admit its performance to be quite equal to what can be done by other known kinds of pumps; but as it is capable of ſome improvement, I am clear that it might be made to raiſe 75 tons per hour inſtead of 60, and with more eaſe to the ſame hands.

It

It may perhaps be imagined that there is ſomething in Mr. GASCOIGNE's machine that is new, and preferable to all thoſe that may be made trial of; but I beg leave to obſerve, that it differs in no eſſential point from the crank machines commonly made uſe of for raiſing water by water or horſes for gentlemen's ſeats, brewers, diſtillers, dyers, &c. though not that I know of applied to ſhips; and in point of raiſing water, I look upon it not quite ſo well adapted as the machine he deſcribes, and calls the ſtore-pump at *Portſmouth*, becauſe a three-necked crank works more equably, and is attended with leſs friction than four: and in regard to his application of an air veſſel, though uſeful on many occaſions, is of no uſe on the preſent; it muſt, however, be allowed, that the form of the pump in ſtore at *Portſmouth* is much more cumberſome, and leſs adapted to the convenience of a ſhip, beſides the inconvenience of ſome of its eſſential parts being above the water line. I apprehend Mr. GASCOIGNE's machine capable of ſome improvements, by which it might be made to raiſe about 80 tons an hour with 14 men, inſtead of raiſing 86 tons with four men, and if its ſituation will be agreeable to the convenience of ſhips, may be uſed to a very good purpoſe.

London, January 20, 1765. J. SMEATON.

BRISTOL HARBOUR and CANAL.

PROPOSALS for laying the ſhips at the quay of *Briſtol* conſtantly afloat, and for enlarging this part of the harbour by a new canal through *Cannon's Marſh*, by JOHN SMEATON.

1ſt. IT is propoſed to keep the water in the quay and new canal to the conſtant height of the 15 feet mark upon the lowermoſt marked ſtaff upon the quay next the *Avon*, and clearing away 2 or 3 feet of the mud there laying, to make from 17 to 18 feet water.

N. B. The 15 feet mark is about 6 feet below the top of the quay, and about 4 feet below the ſpring-tide high water mark of the 24th and 25th of January, 1765, which, though not the largeſt, were nevertheleſs accounted conſiderable tides.

2dly. It is propoſed to dig the new canal as far as the ſluices, ſo deep as to make 18 feet water therein at the ſaid propoſed level, and to make the ſame at leaſt 100 feet wide in the clear.

3dly. To drop the tail of the new canal into the river *Avon* at the bottom of *Cannon's Marſh*, juſt above the *Glaſs Houſe*.

4thly. To conſtruct two ſeparate ſluices, one as near as conveniently can be to the river *Avon*, upon the tail of the canal, the other at the diſtance of 400 feet from the former, further within the canal; both theſe ſluices to be furniſhed with two pair of pointing gates, one pair in each ſluice pointed to land, the other to ſeaward. The width of the chamber, or ſpace intercepted between the two ſluices, to be 60 feet, and the width of the ſluices to be capable of taking in the largeſt ſhips that uſe the port, which I ſuppoſe will be done by an opening of 30 feet wide.

5thly. The threſhold of the upper ſluice to be laid at the depth of 18 feet below the conſtant water that is even with the bottom of the canal; but the floor of the chamber between the two ſluices, as well as the threſhold of the lower ſluice, to be laid as low as the bottom of the river in the ſhalloweſt place, below the tail of the canal.

6thly. Theſe things being executed as before mentioned, the preſent mouth or opening of the river *Froome* into the *Avon* to be ſtopped up by a ſolid dam of earth, furniſhed,

furniſhed, however, with ſuch draw-hatches as may be neceſſary to aſſiſt the hatches in the gates of the ſluices in diſcharging the freſhes of the river *Froome* in rainy ſeaſons, but yet ſo as to make a communication for all kinds of carriages from the *Back* and *Quay* down alongſide of the new canal between the ſame and the river.

7thly. The whole of the new work to be wharfed with ſtone, ſo as to form quays or ſuch other conveniencies as ſhall be found neceſſary.

8thly. To erect draw-hatches at the new bridge at the head of the quay, capable of retaining the water behind them when the water in the new canal and quay is let off.

9thly. To have the command of the hatches, and to erect new ones, if neceſſary, upon the pond of *Newgate Mill.*

N. B. By the conſtructions above propoſed, *Tom's Dock* and *Bridwell Mill* will be rendered uſeleſs, but *Newgate Mill* will be benefited thereby.

OPERATION of the foregoing conſtructions.

When the tide is out, the water of the canal is propoſed to be retained by the land-gates of the upper ſluice, all the reſt being open on tide of flood. As the veſſels come up, they go into the chamber between the ſluices, where they always find equal water with that they came up with, which chamber is capable of holding eight ſhips, or four ſhips and ſix troughs, at the ſame time; here they wait at ſpring tides till the flood in the chamber is upon a level with the canal, at which time the ſea-gates of the lower ſluice are put to, which prevents the tide's water flowing into the canal; the land-gates of the upper ſluice are then opened, and the veſſels proceed to their births.

Then the large veſſels that are going down, that require to depart at high water, are brought down into the chamber while the tide is flowing; the ſea-gates of the upper ſluice being then put to, and the hatches of the ſea-gates of the lower ſluice drawn, the chamber fills to the level of the tide in the river, and the ſea-gates of the lower ſluice are opened; and if any deep veſſels are arrived after the tide had roſe to the level of the canal, they may now be taken in, where they wait all together till high water, when the outward bound depart, with the firſt moment of the ebb, and the inward bound wait till the tide has ſunk to the level of the canal; at which time the land-gates of the lower ſluice are put to, and the ſea-gates of the upper ſluice are opened, which gives thoſe ſhips leave to go to their births, and at the ſame time to take

in ſuch of the veſſels as are outward bound, and can go down with the remainder of the ebb, after the water is fallen to the level of the canal; which veſſels being brought into the chamber, the land-gates of the upper ſluice are put to, and the hatches of the land-gates of the lower ſluice drawn, by which means the water in the chamber is reduced to the level of the tide in the river; the land-gates of the lower ſluice are then opened, and the veſſels depart, leaving the ſluice in the ſame poſition as we found it.

Hence it appears, that two ſets of veſſels may go up and two down in one tide, when the ſpring tides riſe above the level of the canal's water, and that without the admiſſion of any tide-water into the canal, except what happens to get in by the diſturbance of the water by the paſſing of veſſels, which, as it will lodge near the upper ſluice, the greateſt part will be drawn through the hatch of the land-gates of the upper ſluice; which ought to be drawn at low water, to let off the water accumulated in the canal and quays by the currency of the river *Froome*, and to ſcour the chamber and the lower ſluice from the mud left by the tide.

At neap tides the veſſels inward bound come into the chamber as before, as ſoon as they have water, and wait all together till high water, which being below the level of the canal, the land-gates of the lower ſluice are then put to, and the hatches of the land-gates of the upper ſluice drawn; by which means the chamber will fill to the level of the canal, and as the land-gates of the upper ſluice may then be opened, the veſſels may proceed to their births, and thoſe that are ready to go down may hawl in; after which the land-gates of the upper ſluice being put to, and the hatches of the land-gates of the lower ſluice drawn, the water in the chamber is then reduced to the level of the tide in the river; the gates of the lower ſluice may then be opened, and the veſſels proceed with the tide.

When water is plentiful in the river *Froome*, the veſſels going up at neap-tides may be penned through the chamber, by drawing the hatches of the upper land-gates ſome time before high water, which will afford more time for the veſſels going down to get into the chamber before the tide is much abated; otherwiſe it will be moſt adviſeable, that after the veſſels going up are gone out to their births, to keep the water againſt the land-gates of the lower ſluice till the next tide, when all the veſſels going out will have time to get into the chamber, and be ready to go out all together at high water. By this method of paſſing, the veſſels inward bound one tide and outward bound the next, they will all have all the benefit of the full tide, and the whole of the water expended in twenty-four hours will be only ſo much from the canal as is neceſſary to fill the chamber from the level of high water to the level of the canal; and I apprehend the

ſeaſon

feafon is feldom fo dry, but that the currency of the *Froome* will, at an average, replace this to the body of water contained in the new canal and quays in twenty-four hours; but, by way of further fupply, as no water will be wanted from the canal to pafs the veffels in fpring tides, an accumulation of 1 foot may be retained without prejudice, which, upon fo large a furface as will be contained in the new canal and quays, would alone be nearly equivalent to the water expended in the chamber for paffing the veffels, according to the laft propofed method. Yet, as a fheet anchor, the pond of *Newgate Mill* may be had recourfe to, upon paying an equivalent; but which, from the reafon already ftated, I don't apprehend can be wanted above once in feven years.

As by this method the tide-water will be almoft wholly excluded, there will not be a need of often fcowering; but, when this is done, the hatches propofed at *New Bridge* will be of ufe, and the hatches upon *Newgate Mill Pond* will be ftill of further ufe; but I don't apprehend this operation will be needed above twice, or at moft four times a year.

OBSERVATIONS.

1ft. A power of diverting other ftreams into the river *Froome* upon neceffary occafions may be of ufe, and of making refervoirs for water.

2dly. The fea-gates of the upper fluice are to have no draw-hatches, which will effectually prevent the fhips from penning into the canal with the tide's water.

3dly. By thefe conftructions, whenever there is water to bring up a fhip to the tail of the canal, fhe is always enabled to get to the quay.

4thly. The fhips being kept conftantly afloat, the river *Froome* will of itfelf birth a great number, and the new canal will birth twenty-four fhips, befides leaving a fufficient paffage; but, by making it wider, will birth a greater number; every fhip's breadth in width makes an addition of twelve births.

5thly. The expence, as near as I am at prefent enabled to calculate the fame, will be as follows.

	£.	s.	d.
To digging, - - - - -	6555	0	0
Quay walling, - - - - - -	4887	0	0
The two fluices, - - - - - -	8000	0	0
The dam and hatches acrofs the prefent mouth of *Froome* river,	1000	0	0
The hatches at *New Bridge* and upon *Newgate Mill Pond*, -	600	0	0
Contingent expences being fuppofed, - - -	3958	0	0
£.	25000	0	0

Exclufive of purchafe of lands and damages to *Bridewell Mill* and *Tom's Dock*.

Briftol, January 26, 1765.

Briftol, January 26, 1765.

AT a numerous meeting of the merchants of the city of *Briftol*, this day held, JOHN SMEATON, Efq; having prefented to them a fcheme and plan for laying the fhips at the quay of *Briftol* conftantly afloat, and for enlarging that part of the harbour by a new canal through *Cannon's Marfh*, it was unanimoufly voted, that the thanks of the gentlemen prefent be given to Mr. SMEATON for his plan now offered, and for his diligence and attention in this matter.

THO. SYMONS, Clerk.

Aufthorpe, December 31, 1766.

HAVING perufed and confidered the plans this day laid before me relative to *Briftol Harbour*, * I am of opinion, that the uppermoft and lowermoft where the fluices are made out of the river, and the dam upon the channel of the river, are more practicable and eligible than the middle fcheme, where the whole is done within the bed of the river, and provided the expence of the execution of either of thofe fchemes is no objection, there is no other material one that occurs to me; and refpecting the eligibility of the upper or lower fcheme, as there is no difference but what relates to convenience and expence, this is a proper fubject for the determination of the merchants of *Briftol*. But whichever of thefe fchemes are executed, I advife, if two paffages are made, to keep them entirely feparated by a middle wall, and to raife thefe walls and gates at leaft 5 feet higher than the crown of the dam, efpecially at that end next *Briftol*.

J. SMEATON.

* Defigns of Mr. CHAMPION, who came with them into *Yorkfhire* in company with Mr. SYMONS, Clerk of the Company.

PORTABLE

PORTABLE FIRE-ENGINE.

DESCRIPTION of a Portable Fire-Engine, invented by JOHN SMEATON, F. R. S. at the inſtance of the Right Honourable the Earl of EGMONT, 1765.

No. 1. SHEWS the ground plan of the walls for ſupporting the engine, which is ſuppoſed to be neceſſary, in order to keep the ſeveral parts of the machinery from ſettling under the weight, wherein,

A. B. is the pit or ſhaft.
C. C. foundation walls on each ſide of the pit, for ſupporting the fore part of the engine frame acroſs the pit.
D. D. a foundation wall in like manner, for ſupporting the back part of the frame.
E. E. walling under the boiler.
F. ſhews the center of the boiler.
G. the place of the cylinder.
H. the main pump.
I. the jack-head pump.
K. K. the aſh hole.

No. 2. contains elevations of the engine, viz. an end and ſide view thereof, when put together, wherein the ſame letters as are in the plan refer to each.

A. B. is the pit or ſhaft.
C. C. the upright of the foundation walls on each ſide of the pit, for ſupporting the groundſill *c.* acroſs the pit, upon which one ſide of the engine frame is raiſed.
D. D. the foundation wall, for ſupporting the groundſill *d.* upon which the other ſide is raiſed.
E. foundation wall for ſupporting the boiler, and forming the aſh-hole.
F. is the boiler, *f.* the fire-door, *g.* the chimney, *s.* the ſteam-pipe, *p.* the puppet-clack, *v.* the feeding-pipe funnel, *z.* the man-hole.
G. the cylinder.
H. the main pump-ſpear.
I. the jack-head pump, by the continuation whereof *k. k. k.* the water is conveyed into
L. the injection ciſtern.

M.

M. a wheel ſerving inſtead of the great beam, *m.* a rim of a ſmaller diameter, attached to the former, for working the jack-head pump *I.* and plug-frame *Q.*

a. a. pullies to bring their chains into a convenient place for working. The wheel is ſtopped at the end of it's intended ſtroke, which is to be 6 $\frac{1}{2}$ feet, ſtop and ſtop, by means of the two iron fidds *b. b.* which, reaching out on each ſide of the great rim, ſtop againſt two ſtrong iron pins *e. e.* which are fixed into a croſs beam *S.* framed into the piece *T.* and the whole firmly bolted together, as ſhewn in the deſign; *N.* is the injection-pipe, *n* the injection-cock, and *x.* the piſton water-cock.

O. is the hot well.

R. a ſtage for the perſon to ſtand upon, who hands the engine.

P. P. are the two main-beams or ſleepers, upon which the cylinder is ſeated upon it's bottom, and bolted down; the whole is kept from ſpringing or flying off by the iron ſtrap *q.*

N. B. The waſte water-pipes are omitted to prevent confuſion.

No. 3. Fig. 1. ſhews a ſection of the boiler, cylinder, and pipes, with the working-gear, to a larger ſcale, the whole being diveſted of the framing, in order to render every thing more diſtinct.

N. B. The boiler is ſuppoſed to be turned one quarter round, from it's true poſition, as in No. 2. in order that the moſt material parts may be brought into one view. It is alſo to be noted, that every veſſel or pipe is ſuppoſed to be cut right through the middle, in order to ſhew the contents, and not that the ſection is confined to any particular plane; but, for the more perfect explaining of the principal figure, it will be beſt to begin with the little plan marked Fig. 2. wherein

A. B. C. D. is a plan of the cylinder bottom, bolted down upon the two main beams *A. B.* and *C. D.*; the dotted circle *E. F.* ſhews the extremity of the bottom flanch of the cylinder, and the circle *G. H.* the diameter of the cylinder within; the hole *I.* anſwers the ſteam-pipe and regulator; and the hole *K.* the eduction or ſinking pipe, and the circle *L. M.* it's flanch; the circle *N. O.* ſhews the ſize and poſition of the regulator plate, and the dotted circle *P. Q.* the ſize of the receiver, in which the ſliding valve of the regulator *R.* works, and in this poſition is open; *S. T.* is the lever by which it is worked; and when that is brought forwards into the poſition *S. V.* then the valve covers the aperture of the regulator.

Explanation

Explanation of Fig. 1.

A is the boiler, and

B the fire-place, which is intended to be of a ſpherical figure, of caſt iron, and intirely within the boiler; the coals are to be introduced by the large pipe or opening *C* and the ſmoak carried off by the curved pipe *D*; and, in order to promote a ſufficient draft, the iron funnel *E*. is added. The aſhes fall through the grate *S* and wide pipe *F*, into the aſh-holes below. The whole being joined to the boiler by proper flanches, as is ſhewn in the figure, and always covered with water, as will be known by the two gage cocks *a*, *b*.

Though it is expected that a ſmall force of fire thus applied will keep the engine going, yet as that force cannot be wholly exhauſted within the compaſs of the boiler, it is propoſed to ſurround the curved pipe *D* with a copper veſſel, ſomewhat adapted to the ſhape thereof, as repreſented in the figure, in which it is propoſed to bring the feeding water, which will hereby be prepared to a greater degree of heat than if brought immediately from the hot well into the boiler; into which it is to be introduced by the little hole at *c*.

The bars of the grate *S* are intended to be caſt in a looſe ring, capable of being taken out, and replaced when occaſion requires.

T a cock for emptying the boiler when it wants to be cleaned.

G is the cylinder into which the ſteam aſcends from the boiler, by the pipes *d e H I*; of which *d e* are the copper, and are diſunited at *f*, for the ſake of taking the engine eaſily to pieces; and are joined by firſt bending a piece of lead round the joint, and then wrapping them with cloths and cords, as is common in great engines.

H is the receiver for the ſteam, of caſt iron, containing the regulator valve; and *I* is the ſteam pipe, by which the ſteam paſſes to the cylinder when the regulator valve is open, which in the preſent ſituation of the engine it is ſuppoſed to be; in which caſe the piſton *K* will begin to return.

L is the ſnifting clack, at which the ſteam at this inſtant blows out.

M the injection cock, which is now ſhut.

N the injection pipe, which brings down the water from the ciſtern above.

O that part of the injection pipe that conveys the water into the cylinder, when the injection cock is opened, and which terminates in a cap that directs the jet of water perpendicular; the injection cap is in the center of the cylinder, but as part of the termination of the injection pipe lays behind the ſteam pipe *I*, it hinders the complete view thereof; the other parts will perhaps be better deſcribed by an explanation of the operation of the engine.

Operation of the engine.

To render this explanation intelligible, it is to be premiſed, that the plug-frame *P*, which moves up and down with the piſton, but with a different velocity, according to the diameters of the two wheels, (*M* and *m* No. 2) is furniſhed with pins, which lay in four different planes, anſwerable to four different detents or arms of the working gear: the pin 3 lays upon the fore ſide; the pin *g* lays in a mortoiſe, which divides the plug-frame into two parts, the pins *S*, 1, 2, lay upon the far ſide, and the peg *p* ſtands in the place of the plug-frame, upon the further cheek. Now when the piſton is riſen as high in the cylinder as it's ſtroke is intended, the pin *g* having met the arm *h* of the tumbler *i k*, overſets it into the poſition *i m*; ſo that the point *k* moving into the place of *m*, the regulator valve is ſhut, by drawing the rod *k o*, which takes hold of it's lever towards the plug-frame; and at the ſame inſtant the peg *p* riſing ſo as to lift up the catch *q*, the beak of the faller (or *F* as it is commonly called) marked *r*, is diſengaged therefrom, and the weight *w*, by deſcending into the place *v*, carries the fork *x* along with it, and therewith the lever that turns the injection cock into the place *y*, and whereby that cock is opened, the jet played, and the ſteam reduced into water, (or condenſed, as it is commonly called) hereby a vacuum being produced within the cylinder, the preſſure of the air cauſes the piſton to deſcend, and in deſcending, the peg *S*, on the far ſide, meeting the faller at *t*, carries it down to *z*, which ſhuts the injection cock, and alſo hooks the beak behind the catch *q*, and thereby the tail *t t* becoming parallel to the plug-frame, the pins ſucceeding the pin *S*, retain it in the ſame poſition, the piſton ſtill deſcending till the peg 3 on the fore ſide laying hold of the arm 4 of the tumbler at *n*, thereby brings back the regulator into it's preſent poſition, and the further deſcent of the piſton is ſtopped by letting in the ſteam.

The water thrown in by the injection at each ſtroke, and alſo generated from the ſteam, is evacuated while the piſton is riſing, by means of the eduction or ſinking-pipe, and valve *Q*; this pipe laying exactly behind the ſteam-pipe *I*, is thereby, in a great meaſure, hid; the ſteam-pipe is carried ſeveral inches above the bottom of the cylinder, to prevent the injection water from running into the boiler; but the eduction-pipe riſes no higher than the bottom, in order to lead the water into it; and as the bottom of the cylinder is commonly elevated from $1\frac{1}{2}$ to 3 feet above the valve at the bottom of the eduction-pipe, commonly called the horſe-foot valve, the preſſure of this column of water opens the valve, and makes it's way into the ciſtern *R*, called the hot well; but when the vacuum is made, this valve ſhuts, and being immerſed under the ſurface of the hot well water, is thereby kept air-tight.

As

As there is a confiderable quantity of air lodged in water, when in it's natural ftate, which feparates itfelf by boiling, and, in fome degree, by confiderably heating, it follows that a quantity of air paffes along with the fteam into the cylinder, and that a further quantity efcapes from the injection water, by being confiderably heated with the fteam; and though air is capable of being confiderably expanded by heat, and contracted by cold, yet the degree is fo very much lefs than that of fteam, that if the air generated at each ftroke was not evacuated, it would quickly render the vacuum fo imperfect, that the pifton would ftop in the middle of it's defcent. Now as the air will be lodged, when the pifton is down, between the furface of the injection water laying upon the bottom of the cylinder and the pifton, in order to get rid of it, the fnifting clack *L* has been happily applied; for, on the firft rufh of the fteam into the cylinder, the pifton not being inftantly put into a contrary motion, the fteam, finding a paffage at the fnifting clack for a fmall fpace of time, blows out thereat, and therewith carries the whole or the greateft part of the air generated at each ftroke, fo as to prevent it's increafe beyond a certain degree.

The furface of the hot well water being in general from 3 to 5 feet higher than the furface of the water in the boiler, this height of column is fufficient to force it's way into the boiler, though refifted by the action of the fteam within, when fufficiently elaftic for ufe; it therefore finds it's way down the feeding-pipe 5, 6, through the feeding-cock 7, which is opened fo much as is found neceffary for fupplying water to the boiler as faft as it is confumed in fteam. It is evident, that whenever the repellancy of the fteam within the boiler is not too great to fuffer the furface of the water in the feeding-pipe to be below that of the hot well, that the boiler will feed by the paffage of the water into the pipe; but whenever the repellancy of the fteam is fuch as to keep the water in the feeding pipe above that point, that then the water will revert into the hot well; but as the repellancy of the fteam within the boiler is alternately greater and lefs, as the regulator valve is fhut or open, during each ftroke of the engine, it follows that the boiler may feed while the cylinder is drawing the fteam from the boiler, and revert while the pifton is defcending. In order, therefore, to make this matter fafe, and at the fame time to bring the engine into as fmall a compafs as poffible, the valve 8 is placed in a little box in the hot well, to prevent fuch a reverfion. It is neceffary to continue the feeding-pipe as ufual confiderably above the hot well; for as the water is in a vibrating ftate within this pipe, according to the variable repellancy of the fteam within the boiler, this extenfion is to prevent it's frequently overflowing; for it is neceffary to be open at the top, otherwife the fteam generated therein would prevent it's feeding at all, or very irregularly.

N. B.

N. B. The hot well is, in this view of the machinery, repreſented conſiderably larger than it is; for ſuppoſing the boiler turned a quarter round while the feeding-pipe 5 6 falls directly behind the puppet-clack 9, as ſhewn in the general elevation, the hot well will then be ſhorter by half the diameter of the boiler.

The puppet-clack 9 has no other uſe than being loaded with a certain weight, in proportion to it's ſize, that whenever the repellancy of the ſteam in the boiler is greater than to lift up this clack, it evacuates without burſting the boiler, which it otherwiſe might do, and, when the engine is ſtopped, the perſon attending lifts it up by the cord 12, 13, in order to diſcharge the ſteam.

A pipe of communication for ſteam, 10, 11, between the receptacle for feeding and the boiler, will be neceſſary; for while the boiler is heating to make the engine work, (after ſtanding ſome time) the feeding-cock being then ſhut, the water in this receptacle will boil before that in the boiler, and poſſibly, by the ſudden expanſion of the ſteam upon boiling, might burſt this veſſel before the water could be evacuated at the little hole *c*, and yet, if ſo, being emptied of the water, might, by overheating the copper, break the ſoldered joints.

N. B. It is to be underſtood that in this, as in all other engines, the weight of the main pump-ſpear is ſo far to exceed the weight of the piſton as to raiſe it, and overhaul all the gear, and that if not ſo, muſt be weighted till it will do it.

I have ſaid nothing of the meaſures, for as every thing is drawn to the ſcale annexed, I did not chuſe to perplex the account therewith.

Calculation of the effects of this engine.

The diameter of the cylinder being 18 inches, the area in circular inches will be 324 inches, and allowing 7 lb. to the inch, which ſuch a cylinder will very well carry, we ſhall have 2268 lbs. equal to the weight of the column of water to be lifted = 1 ton and 1 quarter of an hundred weight.

The pump working barrel being ſuppoſed of 7 inches diameter, the weight of a column of water that ſize, and 1 foot high, is 16.7 lbs. by which dividing 2268 lbs. to be raiſed, we have 135.9 feet for the height of the column = 22$\frac{2}{3}$ fathoms nearly, by a ſimilar proceſs, if the working barrel is 8 inches, the height of the column raiſed, will be 17$\frac{1}{3}$ fathoms, and if of 9 inches, 13$\frac{2}{3}$ fathoms.

Such

Such an engine may be expected to make ten ſtrokes per minute, of 6 feet each, effectively; this, with the 7 inch bore, will produce $98\frac{1}{4}$ ale gallons per minute, that is 113 hogſheads wine meaſure per hour; the 8 inch bore will produce $128\frac{1}{4}$ ale gallons per minute, that is, 148 hogſheads per hour; and the 9 inch bore will produce $162\frac{1}{2}$ gallons per minute, or 187 hogſheads per hour.

It has been found by experience, that a 2 feet cylinder can be worked by one buſhel of Newcaſtle coals per hour; the preſent cylinder being but 18 inches, the capacities will be as 16 to 9; therefore if a 2 feet cylinder takes 24 buſhels per day, an 18 inch cylinder will take but $13\frac{1}{2}$ buſhels per day, according to the common application of fire; but I have reaſon to think an engine conſtructed like this will not require above 9.

It has alſo been found by experience, that a horſe will raiſe about 250 hogſheads 10 feet high per hour; conſequently only $30\frac{1}{4}$ hogſheads at $13\frac{2}{3}$ fathom $= 82$ feet; but 187 hogſheads raiſed to that height by the engine, is more than ſix times the quantity raiſed by one horſe, and conſequently acts with more than the power of ſix horſes at a time; but in order to keep up this force with horſes, night and day, three ſets will be required, and conſequently this engine will be more than equivalent to eighteen horſes.

WHITBY HARBOUR.

Yorkshire, to wit, At the assizes held at the castle of *York*, in and for the said county, on Saturday the 20th day of July, in the fifth year of the reign of our Sovereign Lord George the Third, by the grace of God, now King of *Great Britain*, &c. and in the year of our Lord 1765, before the Honourable Sir HENRY GOULD, Knight, one of the Justices of his Majesty's Court of Common Pleas, and the Honourable Sir JOSEPH YATES, one of the Justices of our Lord the King, assigned to take the said assizes according to the statute.

CHOLMLEY, Esq; against HOWLETT and MATHEWS.

IT is ordered by the consent of the said parties, and their attornies, that the last juror or jury empannelled and sworn in this cause be withdrawn from the said pannel, and by the like consent it is ordered that the plaintiff shall execute, and the defendants shall accept, a lease with proper covenants for repairs by the defendant, and all other usual covenants, of the plaintiff's mills and fishery, in the pleading of this cause, mentioned at a rent equal to the highest neat profits, to be computed on a mean of any three successive years to be named by the plaintiff, which shall appear to the satisfaction of FOUNTAIN WENTWORTH OSBALDESTON, of *Hunmanby*, SIMON BUTTERICK, of *Thirsk*, and JOHN GRIMSTON, of *Kilnwick*, Esqrs. or any two of them, to have been made at the premises by the plaintiff; and also to enter into such covenants for cleansing the harbour of *Whitby* from the allum shail, which hath come from the defendant's works, within such time and in such manner as JOHN SMEATON, Esq; and JOHN WOOLER shall think reasonable, and also for the security of the said harbour from future damage from the defendant's allum works. The survey and award of the said JOHN SMEATON, Esq; and JOHN WOOLER to be made on or before the 7th day of November next, and at the joint expence of the said parties; and it is further ordered that such security shall be given, and penalties provided for the performance of the aforesaid covenants, as the said FOUNTAIN WENTWORTH OSBALDESTON, SIMON BUTTERICK, and JOHN GRIMSTON, or two of them, shall think reasonable and sufficient, and that the lease to be made shall be executed on or before the 20th day of December next, and shall commence, together with the rent, at that time, for the term of 99 years.

And it is also ordered that there shall be no costs on either side, and that the defendants shall consent that the plaintiff's bill, now depending in the Court of Chancery, shall be dis-

missed

missed without costs; and that all other proceedings or actions now depending between the said parties, either at law or in equity, touching the matter in question in this cause, shall cease, and that no writ of error shall be brought, and that no bill in equity shall be filed against the said FOUNTAIN WENTWORTH OSBALDESTON, SIMON BUTTERICK, JOHN GRIMSTON, JOHN SMEATON, and JOHN WOOLER, or any of them, for any thing done by them under or by virtue of this order; and that this order shall be made an order of his Majesty's High Court of Chancery, if the Lord High Chancellor shall so please.

By the Court.

To all to whom these presents shall come, JOHN SMEATON, of *Austhorpe*, in the county of *York*, Esq; and JOHN WOOLER, of *Whitby*, in the said county, Gent. send greeting. Whereas, by rule of court, made at the assizes held at the castle of *York* in and for the county of *York* on Saturday the 20th day of July, in the 5th year of the reign of our Sovereign Lord George the Third, by the grace of God, now King of *Great Britain*, and so forth, and in the year of our Lord 1765, before the Honourable Sir HENRY GOULD, Knight, one of the Justices of His Majesty's Court of Common Pleas, and the Honourable Sir JOSEPH YATES, Knight, one of the Justices of our Lord the King, assigned to hold pleas before the King himself, Justices of our said Lord the King, assigned to take the said assizes according to the statute, &c. in a cause then and there depending between NATHANIEL CHOLMLEY, Esq; plaintiff, and SAMUEL HOWLETT and JOHN MATHEWS, Gents. defendants, it was ordered, by the consent of the said parties and their attornies, that the last juror of the jury impannelled in the said cause should be withdrawn from the said pannel, and by the like consent it was ordered (among other things) that the said defendants should enter into such covenants for cleansing the harbour of *Whitby* from the allum shail, which had come from the defendants works, within such time and in such manner as we the said JOHN SMEATON and JOHN WOOLER should think reasonable, and also for the security of the said harbour from future damage from the defendants allum works. The survey and award of us the said JOHN SMEATON and JOHN WOOLER to be made on or before the 7th of November then next, as by the said rule of court, reference thereunto being had, may amongst other things fully appear. Now know ye, that we the said JOHN SMEATON and JOHN WOOLER having viewed, surveyed, and examined the said harbour of *Whitby* and the river *Eske* as far upwards as *Ibrondale Beck*, and the said *Beck* as far as the allum works of the said defendants, which are situate and lying contiguous to or near the said *Beck*, and also the said allum works, we find that not only the harbour of *Whitby* above the bridge there, but the channel of the river *Eske* as far upwards as the said *Ibron-*

dale

dale Beck, is greatly obstructed with allum shail, and also that the channel of the said *Ibrendale Beck* is greatly obstructed, and in some places nearly filled up, by the allum shail therein; and that the allum shail being in the said harbour, river, and beck as aforesaid, has all proceeded from the said allum works of the defendants, and has been carried down into the said river and harbour, in the time of floods and freshes, from the said beck; and that the said harbour of *Whitby* above the bridge there is greatly damaged thereby; and we also find that the manner in which the said allum work is carried on is such as will occasion still greater damage to the said harbour than it has yet received, by reason of other great heaps of shail and rubbish, from time to time proceeding from the said works, must necessarily fall into the said beck, and by the waters passing through the same in time of floods and freshes be washed and carried down into the said river, and from thence, by the said waters, and the additional waters coming down the said river above the said beck, carried into the said harbour, and there scattered about in an irregular manner, to the great detriment thereof, and particularly by filling up and choaking the channel of the said river, where ships of great burthen lay or have usually laid between the bridge of *Whitby* and about 160 yards above a place called the *Oil House*, and which was formerly called the *Stone Key*.

We do therefore order, adjudge, determine, and award, that the said defendants and their or one of their heirs, executors, administrators, or assigns, or some of them, shall effectually cleanse the present channel of the said river *Eske*, running through that part of the said harbour of *Whitby* laying above the bridge therefrom, and remove and carry away all the allum shail that shall be found at the time or times of such cleansing laying in the said river or harbour, between the said bridge of *Whitby* to 160 yards above the south east corner of the building or warehouse now commonly called the *Oil House*, and which was formerly called the *Stone Key*, and which shall be found above the surface of a plane regularly inclined so as to be 14 feet below the top of the uppermost aisler course of stone in the present south east angle of the said *Oil House* as it now is, and 16 feet below the top of the uppermost aisler course of stone under the threshold of the door on the east side of the warehouse or storehouse belonging to Mr. PLUMMER, being situate contiguous or near to the west end of the said bridge; and also that they shall take and carry away all such allum shail as at the time or times aforesaid shall be found laying on the sloping sides of the said channel.

And we do further order, determine, and award, that the said defendants and their or one of their heirs, executors, administrators, or assigns, or some of them, shall effectually make, do, and perform, or cause to be effectually made, done, and performed, all such cleansing of the said river and harbour as herein before ordered and awarded, on or before the 29th of September, which shall be in the year of our Lord 1766.

And

And we do further order, determine, and award, that the said defendants and their or one of their heirs, executors, administrators, or assigns, shall from to time, after the said 29th of September, 1766, take away and remove, or cause to be taken away and removed, all such allum shail as shall be found above the level of the plane above specified, or laying upon the sloping sides of the said channel; which allum shail we adjudge must happen to be so found or laying so long as the said allum works of the said defendants shall be carried on in the manner they are at present, and so long afterwards as any of the shail proceeding therefrom, and laying in the said beck and river above the harbour of *Whitby*, shall remain therein in a state capable of being removed by floods. And we do also further order, determine, and award, that all such allum shail as shall, on cleansing the said harbour aforesaid, be taken away, shall be by, or by the order, and at the cost and charges of the said defendants, their or some of their heirs, executors, administrators, or assigns, carried or removed and lodged above the high water mark of spring tides, and deposited and laid in such a manner as no part thereof may at any future period of time slide or fall down into the said harbour, or otherwise that it shall be carried directly to sea, and discharged there in not less than 14 fathom of water. And lastly, we do order, adjudge, determine, and award, that the said defendants shall, within 40 days after the date of this our award, enter into and make, and duly execute, a deed of covenants between them and the said NATHANIEL CHOLMLEY, or his heirs, wherein and whereby the defendants shall, for themselves and each of them, and their and each of their heirs, executors, administrators, and assigns, and every of them, jointly and severally covenant, promise, and agree to and with the said NATHANIEL CHOLMLEY, and his heirs and assigns, that they the said defendants, or their or one of their heirs, executors, administrators, or assigns, or some of them, shall and will from time to time, and at all times hereafter, at their own cost and charges, well and truly make, do, perform, and execute, or cause to be well and truly made, done, performed, and executed, all and every the act and acts, thing and things whatsoever, before by us ordered, directed, determined, and awarded to be by them, or any of them, made, done, executed, and performed, or cause to be made, done, executed, and performed as fully and effectually, and at or within such time or times, and in such manner as herein before mentioned, and according to the true intent and meaning of this our award. In witness whereof we have hereunto set our hands and seals this 18th day of October, in the year of our Lord 1765.

Signed, sealed, published, and declared by the above-named JOHN SMEATON, as his final award and determination, in the presence of us.

Signed, sealed, published, and declared by the above-named JOHN WOOLER, as his final award and determination, in the presence of us.

MARKET WEIGHTON.

HAVING viewed the out-fall cloughs of *Furſdyke* and *Hudlett*, as well as the leading drains up to *Hotham Carrs*, and from thence the country between this and *Market Weighton*, it appears to me as follows:

1ſt. That the moſt flooded part of thoſe levels is *Hotham Carrs*, and parts adjacent to *Wholſea*.

2d. That the general ſurface of the lands in thoſe *Carrs* lay at leaſt 7 or 8 feet above the floor of *Hudlett Clough*; and therefore,

3d. That by ſufficient drains the ſurface of the water might be reduced 5 or 6 feet in *Hotham Carrs*, oppoſite *Wholſea*, even as *Furſdale* and *Hudlett Cloughs* now ſtand; and therefore

4th. That all the drainages which come to *Hotham Carrs*, by way of *Foulney* or *Black Dyke*, &c. may be equally reduced and improved; and conſequently,

5th. That all the adjacent country may by proper branch drains be refitted in like manner, by running their waters proportionably lower than they can by the preſent drains.

6th. It appears that *Hudlett Clough* (which I look upon to be lower than that and *Furſdyke*) lays at leaſt 3 feet above low water mark ſpring tides; and therefore,

7th. That by erecting a new clough of proper dimenſions, the waters might be run off at leaſt 3 feet lower than they can poſſibly be done by the preſent cloughs, though the drains leading thereto were perfect.

8th. That from *Hotham Carrs* the low grounds have a conſiderable riſe towards *Market Weighton*; and conſequently, that

9th. The affair, ſo far as regards to the drainage of theſe levels, will be perfectly eaſy and well conditioned, and executed at a very moderate expence, in proportion to the extent and value of the lands to be benefited thereby.

10th.

10th. Refpecting navigation, it is no ways incompatible with drainage; for provided the cuts are made at an average from 18 inches to 2 feet deeper, the drainage will remain equally good, as if no navigation.

11th. A navigation may be made any where by means of locks, where there is water to fupply them.

12th. Several locks will be required between the *Humber* and *Market Weighton*, befides the fea-lock; I apprehend at leaft 4.

13th. I am of opinion, that the brooks formed from the fprings of *Saneton* and *Houghton*, which form *Beal's Beck*, the fprings at *Godmanham*, which form *Weighton's Beck*, and thofe of *Londebrough*, forming *Shipton Beck*, when united, as they may eafily be near *Weighton*, are amply fufficient for fupplying the navigation-locks thither in the drieft feafon, and I am inclined to think the two former becks will be fufficient, exclufive of the latter; but of this I cannot be certain, unlefs I faw the currents of thofe becks in the drieft feafons.

14th. I apprehend it will be equally evident from the fame principles that a navigation is practicable through the levels towards *Pocklington*, as I am informed the fupply of water that way is at leaft equal if not better; but as I fuppofe *Pocklington* lays in an higher fituation than *Weighton*, a greater number of locks will be needful on that account.

15th. It is not poffible to afcertain any thing refpecting the coft of drainage or navigation towards either the towns of *Weighton* or *Pocklington*, without an actual furvey of the principal drains, with a fketch of the adjacent country, as alfo an accurate level taken from the low water mark at the *Humber*, diftinguifhing the heights of the relative furfaces of the water and lands up to the refpective points where the navigation or drainage is fuppofed to terminate.

November 29, 1765. J. SMEATON.

A NEW BUCKET.

Defcription of a new Bucket for Fire Engines.

N. B. The fame things are marked with the fame letters, both in the plans and fection.

Fig. 1ft. A A is a ring of brafs about $\frac{3}{4}$ of an inch thick, to be turned upon the edge fo as to fit the working barrel as near as poffible, but not to ftick in any part; but it will not be a fault if not more than $\frac{1}{16}$ of an inch lefs than the barrel: this being prepared, all the reft is made from it.

Fig. 2d. B B is a ring of forged iron, about 1 inch thick, and turned or filed round upon the edge, fo as to be about $\frac{1}{4}$ of an inch lefs in diameter than the brafs ring; this ring muft be pierced with 4 oblong holes or mortices C C C C, of 1 inch long and $\frac{1}{4}$ inch wide, and 8 round holes *a a*, &c. which are to be tapped fo as to take an $\frac{1}{2}$ inch fcrew. This ring is alfo furnifhed with a bridge or bar D D, which may either be made of one piece with the ring, as reprefented at the end *d*, or let in with a dovetail, and rivetted, as reprefented at the end *e*, either way, as the fmith can beft do it, fo as to make all level on the upper fide. The bridge is alfo furnifhed with 3 round holes of the fame fize, and tapped as the former.

Fig. 3d and 4th. By means of the 4 fquare holes, the iron ring is to be faftened to the end of the fpear rod, whofe bottom part is to be divided into 4 branches, two of which, E E, are fhewn in the upright fection, fig. 4, and the horizontal fections thereof, fig. 3, fuppofed to be cut off a little above the ring, are marked with the fame letters; the dotted lines diftinguifh the mortices, as in fig. 2d, and what lays without fhews the fhoulders, againft which the upper fide of the ring is brought fquare, and rivetted on the under fide, by means of the tapt holes in the iron ring, and the plain holes in the brafs ring, which are to be made anfwerable to each other; the 2 rings are to be fcrewed together by 8 fcrews, fuch as reprefented *f f*, &c. and betwixt the rings is to be fcrewed the leather *g g g*, &c. turned up round the iron ring like a difh, the fkin or hair fide being next the iron ring, and the oppofite or flefh fide next the barrel, the middle part of the leather being cut out anfwerable to the infide of the rings.

H H are the valves which are to be fcrewed down upon the bridge by 3 crews *i i i*, which confine down the rider K K, which is to be fomewhat floped and rounded toward

ward the under ſide, to give more room for the leather of the valves to bend in the joints. I I are the upper plates upon the valves, and *m m* the under, which ought to be thin, to prevent ſtopping the water.

N. B. Small ſcrew bolts with thin flat heads laying underneath, will be preferable to rivets for the valves, as the leather may be more eaſily ſhifted.

L, the ſhank, where the 4 arms are joined into one, by which it muſt be united to the take-off joint.

OBSERVATIONS to be regarded in making the above.

1ſt. The braſs ring had beſt be caſt without holes, that when the holes in the iron ring are tapped, the braſs may be marked off from it, drilled, and opened anſwerable to the iron.

2d. The iron ring had better not be edged till the two rings are ſcrewed together, by which means the border may be reduced to a breadth all round.

3d. The ſquare mortices muſt be chamfered or opened on the under ſide, in order to receive a firm rivet when filed flat, and particularly end-ways; for this purpoſe the mortice ſhould be at leaſt $\frac{3}{8}$ longer and $\frac{3}{16}$ wider below than above, and the ſlope to reach $\frac{3}{8}$ upwards at the ends, and about $\frac{5}{16}$ at the ſides.

4th. Particular care ſhould be taken, that the tenons of thoſe mortices at the end of the branches ſhould be ſound and tough iron, but not the ſofteſt, and that they may be rivetted with a hammer as heavy as a common hand hammer, that the metal may ſpread as well within as without.

5th. The tenons of the branches, I believe, had beſt be formed angle-wiſe upon 4 ſquare bars, for then they will be in right poſition, when laid flat together, in order to be welded into one.

6th. The leather diſh is to be formed as follows. Prepare an iron hoop about $1\frac{1}{2}$ inch broad, as near as poſſible the ſize within of the barrel, but better leſſer than bigger; prepare alſo a round plug of wood the ſize of the iron ring, Fig. 2d. but rather bigger than leſs; let the plug be turned truly round, of ſome cloſe wood, and ſquare at the end; let your leather be of the beſt bend, but not the thickeſt; thoſe are beſt that are eveneſt of a thickneſs; cut out a circle of leather $2\frac{1}{2}$ inches more in diameter than the pump barrel, therefore for a nine-inch barrel $11\frac{1}{2}$ inches. When the leather is well ſoaked

ſoaked in water, lay it upon the ring, with the hair ſide uppermoſt, ſet the plug upon it, and with a few blows of a beetle, the leather will be forced into the ring, and will turn up round the ſides in the ſame manner it is to lay in the pump, and thereby form a border without a joint of about $1\frac{1}{4}$ inch broad. When it has ſtood a while take it out, and put it upon the iron ring of the bucket, and with a round-faced hammer beat the leather a little down upon the ring oppoſite to the holes, by which means their places will be marked; cut them out with any proper ſharp tool, but the beſt is a leather punch, which is made for the coachmakers, big enough for this purpoſe. This done, ſcrew it into its place, trim it to an equal breadth, and chamfer the edge towards the barrel, as repreſented in the ſection, and cut out the middle anſwerable to the rings. In this way ſeveral leathers may be prepared at once, provided thoſe that are to be kept are put on round boards, or ſomething to keep them from drying into a leſſer diameter. As the wet dries out, keep ſupplying them with oil, either train oil or ſweet oil, or any oil that is not of a drying nature, till the pores of the outward rim of the leather that works againſt the barrel be in a good meaſure ſaturated therewith, and let this be done for the firſt leather as well as the reſt; when the bucket is lowered down into its place, it would be well to pour down about $\frac{1}{8}$ of a pint of oil round the ſides of the barrel, by which means, when the engine makes a ſtroke, the inſide of the barrel will become beſmeared therewith; but oil in the bending joints of the valves is rather to be avoided.

N. B. If on cutting out the circle of leather from the hide it appears thicker on one ſide than the other, let it be ſhaved with a ſharp knife, ſo as to be of an even thickneſs.

If a barrel is very ſmooth bored without ring-galls, I eſteem the ſurface beſt that is left by the tool; but if otherwiſe, let it be rubbed with a fine grit-ſtone; none better than the grindſtone kind that is got on *Gateſhead Fell*. After the barrel is bored or cleanſed as above, let its inſide ſurface be oiled over, which will prevent its immediate ruſting; and if ſo preſerved till uſed, will make a great difference in the firſt leather.

The tenons at the end of the branches, by which the whole column is to be ſuſpended, will undoubtedly ſeem ſmall and weak; but it is to be remembered, that the bucket I ſaw at *Aller Dean* hung by two parts of barely $\frac{5}{8}$ ſquare each, that is 50 ſquare eighths; whereas 4 Parts of 1 inch by $\frac{1}{2}$ are equal to 64 ſquare eighths. After all, a column of 27 fathom and 9 inches diameter weighs but 2 tons, ſo that each part has only 10 cwt. to carry; therefore there is no doubt of their ſufficiency, if good iron and well put together.

N. B. There is no objection to lengthening the mortices.

Auſthorpe, 11th December, 1765. J. Smeaton.

THURLSTON MILLS.

The REPORT of JOHN SMEATON, Engineer, touching the matter in dispute between Mr. RICH and Mess. WALTONS, concerning their mills at *Thurlston*.

AS no particular question has been formally stated to me in writing, I apprehend the matter in dispute to be reducible to the following, viz.

Whether Mess. WALTONS have done any thing, by the erection of their oil mill dam, which they have no right to do, and whereby Mr. RICH's corn mill may at certain times be affected, and stopped by back water?

As it will save many words, I refer to a sketch of the river and premises in question, hereunto annexed.

The rule that I have constantly followed myself in regard to the placing intermediate dams, whether for the erection of mills or navigations, and the same rule I have found practised by the best engineers and millwrights, and which is found generally subsisting in ancient mills. In flat countries, where levels are scarce, and consequently tail or back water most burthensome and annoying, is to build those dams so, that each dam shall not pen into the wheel of the mill next above, when the water is in it's ordinary summer's state.

This rule I apprehend to be founded upon the following reasons: that if the erection of a dam does not affect the mill above by tail-water, when water is the most scarce in dry seasons, as every mill that is well and properly constructed will clear itself of a considerable depth of tail-water when it has an increase of head and an unlimited quantity of water to draw upon the wheel; and as in freshes and floods, at the same time that they bring a quantity of tail-water upon the wheel, they also increase the head, and afford a superior quantity to be expended. This is looked upon to be the proper means, and equivalent, by which mills are to be cleared of back-water, as far as is consistent with the mutual enjoyment of those great benefits of nature, namely, falls of water; and that this alone is very sufficient, appears from hence, that, in common, mills will bear 2 feet of tail-water when there is an increase of head, and plenty of water to be drawn upon the wheel, without prejudice to their performance; but

mills

mills well conſtructed will bear 3 and even 4 feet and upwards of tail water; I have ſeen an inſtance of 6 feet; and it is a common thing in level countries, where (as ſaid before) tail water is moſt annoying, to lay the wheels from 6 to 12 inches below the water's level of the pond below, in order to increaſe the fall of water, and, if judiciouſly applied, is attended with good effect.

If the rules above laid down are not deciſive betwixt man and man, I believe it will be difficult otherwiſe to draw the line; for while ſome may think 3 inches a ſufficient clearance, others may think 3 feet too little; and a third may ſubject himſelf to an action at law, after having been at a great expence and upon the beſt advice, for having done ſomething to interrupt the free paſſage of the water 30 feet perpendicular below another's works, for there is no limits to fix the extent of imaginary evils.

I ſuppoſe it is a rule in the law, that no man can poſſeſs his own property in any new manner, that may be detrimental to his neighbour; but then I ſuppoſe it is equally a rule, that no man can acquire an excluſive power over another's property, to prevent him from turning it to profit, in the ſame manner as the firſt had done before him. It would ſeem very ſtrange and unreaſonable, and alſo very detrimental to the publick ſervice, (of which the benefit of mills and machines worked by water is ſo great as ſcarcely to be eſtimated) I ſay it would ſeem very ſtrange, if I have an eſtate through which a river flows, to which no one has any controul but myſelf, in which there is 10 feet fall, and I have an occaſion for a mill as well as my neighbour, that I cannot pen up the water to the ſame height as it before entered my grounds, and let it go at the ſame level as it uſed to depart, becauſe the miller above ſays, that by keeping up this body of water within my ground, the water does not get away from his mill ſo freely in time of floods and freſhes as it uſed to do; and the miller below ſays, Sir, you ſhall not build a mill there, becauſe I cannot have the water from the mill above I uſed to do, but will be intercepted by your dam. To the former I ſhould anſwer, the water ſhall have the ſame paſſage into my eſtate as it always had, but I *abſolutely deny* that you have ever had any right or occupation of a fall within my land; it is true, I have not made uſe of it myſelf before, but as I always had it in my power to do ſo, as you have done before me, if my not doing it ſo long has been an advantage to you, you ought to thank me for having it ſo long, and not to think of precluding me from making the ſame advantage of the fall within my land, as you have done in yours.

To the miller below I ſhould anſwer, you ſhall have the water delivered to you at the ſame level as before, and in the ſame quantity, for I neither intend to bottle it up, nor

divert

divert it from you; but as I have the prior right of uſing the water paſſing my premiſes, this I ſhall do in the ſame manner as you will do after me.

Thus much by way of explanation of thoſe principles and maxims that it my opinion either are, or ought to be, the medium by which diſputes of this kind ought to be adjuſted. If they are true and valid, as they appear to me to be, there is not the leaſt foundation for a complaint from Mr. RICH on account of Meſſ. WALTON's oil-mill dam; for it appears to be below the floor of Mr. RICH's mill-race no leſs than 1 foot 4 inches, and 10 inches below the bottom of the wheel, in the whole 2 feet 2 inches fall in the compaſs of leſs than 100 yards from the wheel complained of to be put in back-water by the ſaid dam: on the contrary, had Mr. WALTON penned conſiderably higher than he has done, he would not, in my opinion, have infringed upon the true rules of mill-building, eſpecially in ſuch a country as this, where the river runs ſo rapid as ſeldom to lay any mill in back-water above three hours together, and ſcarcely ever above ſix, not even the wheel complained of.

It is obſervable, that Mr. WALTON's dam pens dead water a conſiderable way up Mr. RICH's goit towards the letter P; but as this goit is without any floor laid, it may happen that a flood coming and waſhing in gravel, &c. may raiſe the goit's bottom, while it is above Mr. WALTON's dam's water; or Mr. RICH, by clearing the goit, may at pleaſure ſink it below; or the continual wearing of the mill's water may ſink it below; as therefore the bottom of an unfloored goit is of an uncertain level, nothing concluſive can be deduced therefrom: thus much however it is certain, that no part of the oil-mill's dam's water reaches any part of Mr. RICH's goit where any floor or ſetting is.

How far exactly Mr. RICH's premiſes extend down the river, I know not; but according to the rules already laid down, if Mr. WALTON has penned the water ſo as to raiſe its ſurface againſt Mr. RICH's freehold, he has done what in my opinion he cannot vindicate; it is however very manifeſt, that a conſiderable length of the tail of the jetty has at ſome time or other been taken off the river, as appears by the river's contracted breadth oppoſite thereto; and if, by conſent of the Lord of the Manor, he has obtained a right of making this fence for the more effectually keeping open his water-courſe, he has not thereby deprived the Lord of the Manor of the uſe of ſuch part of the perpendicular fall of water, as Mr. RICH has not by preſcription or otherwiſe obtained the uſe of; for the ſufferance of the Lord of the Manor, in letting a part of the natural fall of the river lay vacant, next below Mr. RICH's premiſes, muſt be conſidered in the ſame light as every other part of the unoccupied fall below.

I ſhall now proceed to a determination of this ſimple queſtion, whether Meſſ. WALTON's oil-mill dam does or does not affect Mr. RICH's mill by back water, in any degree whatſoever, as they now both ſtand? In order to this it muſt be remembered, that the bottom of Mr. RICH's mill wheel lays 2 feet 2 inches above Mr. WALTON's dam water, that is, higher by 2 feet 2 inches than the water under the bridge when the oil mill-pond is full: the water therefore under the bridge muſt be riſen 2 feet 2 inches before it comes upon a level with the bottom of Mr. RICH's mill wheel; and I look upon it as a certainty that Mr. RICH's mill would be going when the water was 18 inches higher than that, provided there were no impediments betwixt the bridge and mill, and the wheel itſelf properly conſtructed. Suppoſe then the water riſen to that height under the bridge, that is, 3 feet 8 inches above the dam's height, in which caſe its mean depth under the bridge will be about 4 feet 8 inches upon 26 feet wide. Suppoſe now Mr. WALTON's dam away, and the water tumbling from the rock at E, in the manner it is ſaid formerly to have done, ſtill not above a certain quantity can be vented through the bridge at that given height, no more than can be vented over a dam at a given thickneſs, though unimpeded by any thing. According to my computation, the quantity that would be vented over the rock and through the bridge at 4 feet 8 inches deep, (ſuppoſing the dam away) would be vented over the dam, which is 84 feet in length upon the crown, at a depth of 2 feet $1\frac{1}{2}$ inch, or thereabouts. Hence it appears, that in this ſtate of the river there will be a fall from the bridge into the mill-pond of $18\frac{1}{2}$ inches, at which difference the bridge and rocks will vent the ſame water as if the dam was away. This may appear ſomewhat paradoxical, to thoſe unacquainted with theſe matters; but it is well known that a ſtream of water iſſuing from a ſluice, or opening, will run the ſame quantity ſo long as it clears its tail, as if unaffected by tail water. At this height the balance is ſtruck, and if at this height Mr. RICH's mill is not going, it muſt be owing to ſome impediments between the bridge and the mill, or to ſomething wrong in the conſtruction of the mill itſelf; at all greater heights the effect of the dam upon the water above is leſs, at all leſſer heights it is greater; but if Mr. RICH's mill ought to go at the height above mentioned, it ought to go at all leſſer heights, and if it will not go at leſſer heights, it is very plain there is ſome obſtruction between the mill and the bridge.

That there are in fact ſome obſtructions, appear manifeſt from what JONATHAN LOCKWOOD the millwright alledged, that is, that Mr. RICH's mill was in back water before the gravel bed in the oil-mill dam was covered; if ſo, ſince no part of the gravel bed was above 9 or at moſt 10 inches above the dam's water when full, it will appear that Mr. RICH's mill is in back water, when the ſurface of the water in the oil-mill dam (below the rocks) is 1 foot 4 inches below the bottom of Mr. RICH's mill wheel: hence it appears, that very great obſtructions are interpoſed betwixt the rocks and Mr.

Rich's mill wheel. Nor indeed does it need the evidence of Mr. Lockwood to confirm this, the evidence arising from the things themselves being to me more strong, than that of any man living; for as soon as I set eyes upon Mr. Rich's mill tail goit, which is some distance below the covered part, not above $4\frac{1}{2}$ feet wide, and seems still less where covered; when I observed that both wheels delivered into the same goit, and the breast wheel in a very bad angle, as represented in the sketch, so that the breast mill stream must greatly obstruct the other; add to this, that instead of two small wheels of about 20 inches wide each, Mr. Rich has built one wheel of 5 feet wide, said to be able to drive three pair of stones at once, it is evident that the superior quantity of water necessary for this purpose, and the additional quantity necessary to be laid on after the tail water begins to touch the wheel; this again, added to the additional quantity also necessary on the same account to be drawn on the breast wheel, and this all crammed together into the same narrow goit that subsisted before the improvement; I say all this considered, it is very evident, that Mr. Rich's mill must be choaked with water for want of sufficient vent. But this is not all; for as the jetty or fence that divides the tail of the goit from the river, as it narrows the river from about 30 feet, which is about the general width, to 21 feet, this will cause the water to swell at least a foot in the contracted part of the river alongside the jetty, when the river is 3 feet 8 inches at the bridge above dam's height; and as the jetty itself, for about 60 feet above the tail, is not at a medium much more than 3 feet above the dam's water, it follows that before the water will rise to the height aforesaid, it will flow freely over the jetty for almost 100 feet upwards into the goit, and thereby fill the goit to nearly the same height as the water in the river abreast of the jetty, which, added to the obstructions before mentioned, must necessarily lay fast the over-shot wheel, long before the water rises to the height under the bridge above specified, according to Jonathan Lockwood's observation.

From what is above laid down it appears, that when the water rises 3 feet 8 inches perpendicular at the bridge above the dam, that then the dam has no obstruction, because the dam will then vent the water as fast as it could have been vented through the the bridge and over the rocks if no dam was there: but this supposes a free passage for the water between the rocks and the dam. How far the gravel bed at this height of the river acts as an obstruction, (the water being at that time not less than 79 feet wide across the gravel bed) is not easy to say, without seeing the river in that state, the obstruction arising from the gravel bed not being subject to computation on account of the irregularity of its figure: however, as it must add something, especially at lesser heights, I would advise Mess. Waltons, for the sake of peace and good neighbourhood, (provided Mr. Rich will be contented therewith) to oblige themselves, on or before *Michaelmas Day* annually, so long as their dam shall remain where it now is, to remove all such gravel as shall be found

in their mill-pond below the rocks, and within the ſtraight line from the ſouth end of their dam, to the ſouth ſide of the river where the rocks are, as ſhewn in the ſketch *r s*, and to clear the ſame ſo that every part may be at leaſt 8 inches below the top of their dam boards, and to lay the matter thence taken in ſuch manner as not to be ſubject to get in the ſame place again. On the other hand, as it does not appear to me that Meſſ. WALTONS have done any thing but what they may juſtify; and further, that on the ſtricteſt examination it does not appear that Mr. RICH's mills receive any prejudice from Meſſ. WALTONS' works, but that the impediments found therein ariſe from the miſconſtruction of Mr. RICH's own works, I adviſe Mr. RICH, (if Meſſ. WALTONS will comply in removing the gravel bed as already ſpecified) for the ſake of peace and good neighbourhood, to be contented therewith, and drop all further proſecutions.

J. SMEATON.

Auſthorpe, December 14, 1765.

HUBBERT's

HUBBERT's MILL STREAM.

The REPORT of JOHN SMEATON, Engineer, concerning the power of HUBBERT's Mill Stream to raise water.

HAVING examined the capacities of the water-way at HUBBERT's mill, situated upon a branch of the river *Coln*, near *Drayton*, in the county of *Middlesex*, I found them as follows, upon the 23d of February, 1766: at which time the currency of this branch of the river was said to be nearly the same as it always is when the mills above, upon the same branch, are at work, or their waste gates drawn, by which means the quantity of water going down this stream is regulated.

	Cube Feet per Min.	
At *Hubbert's Mill* the discharge by a waste gate within the mill was - -	2166	
By the water falling over the top of the waste gates without the mill - -	396	
Total discharge in cube feet per minute - - - -	2562	
	Feet	Inches.
The whole fall or difference at the mill was at this time - - -	5	7

By the help of an hydraulick engine, properly constructed upon that head, and with the quantity of water above specified, the quantity of 356 feet cube thereof may be raised per minute to a perpendicular height of 20 feet above the level of the mill pond, which quantity amounts to 2517 hogsheads per hour, accounting 52 ale gallons to the hogshead.

N. B. If the height is greater or less than 20 feet, the quantity will be inversely as the height.

It further appears on inspection, that the tail-water of HUBBERT's mill (which stands upon a bye stream of the river *Coln*, as already mentioned) is nearly upon a level with the head water of Lord UXBRIDGE's mill below, which stands upon the main river; and that the tail-water of HUBBERT's mill being conveyed by a meandering course, a full mile in length, falls into the main river below Lord UXBRIDGE's mill: hence it is to be inferred, that in the tail-stream of HUBBERT's mill there is a fall from that mill to the main river equal to the fall at Lord UXBRIDGE's mill, which being measured the same day was 5 feet 6 inches, the greatest part of which perpendicular descent may be added

to

to that of HUBBERT's mill-fall, without affecting any other; that is, by ſtraightening, widening, and deepening the ſaid tail-water courſe from the main river to HUBBERT's mill.

Now this being done in a moderate degree, will add 4 feet to the fall of HUBBERT's mill, and ſtill leave 18 inches for the declivity of the tail-ſtream; in which caſe, the quantity raiſed will be greater than before; that is, inſtead of 2517 hogſheads raiſed per hour, the quantity of 4138 hogſheads will be raiſed in the ſame time; but by a ſtill greater enlargement of the tail-ſtream to about a 15 feet bottom, brought upon a dead level at the depth of 11½ feet below HUBBERT's mill full head mark, it is practicable to add 5 feet to HUBBERT's mill-fall, leaving only ½ a foot declivity in the tail-ſtream, in which caſe the quantity raiſed per hour will be 4482 hogſheads.

At other heights the quantities that may be raiſed are expreſſed in the following table.

It is further to be noted, that, according to the information of the millers, the river *Coln* in the drieſt ſeaſons is not leſs than half of what it was upon the day abovementioned; ſo that HUBBERT's mill can then go at leaſt half its time, and with the ſupply above ſpecified; but by information that Mr. FORDYCE afterwards procured, they never are obliged to ſtop above 7 hours in 24.

The drieſt months, it ſeems, are Auguſt, September, and October, ſo that as the ſcarceſt time for water is when there is the leaſt occaſion for it at *London*, and as we may reckon upon a conſtant ſupply during the winter and ſpring months equal to what is above ſet forth, that is, during all ſuch times as the town is fully inhabited, it follows that we may, in effect, compute upon the ſame ſupply throughout the year.

The whole quantity of water current in the river *Coln*, at the time abovementioned, was aſcertained, by obſerving that two waſte gates at Lord UXBRIDGE's mill being drawn, at that time diſcharged the currency of the main ſtream, the dimenſions of the openings of thoſe gates being taken, the quantity of water iſſuing was from thence computed; this, added to the quantity diſcharged by the bye ſtream at HUBBERT's mill, conſtitutes the whole quantity, amounting to 10463 cube feet per minute, that is of 73978 hogſheads per hour, produced by the river *Coln*: the proportionable quantity thereof propoſed to be taken into the new canal, is ſet forth in the following table, according to the different quantities that a different fall at the mill, and height to which it is to be raiſed, will be produceable of, and is contained in the laſt column.

A TABLE,

A TABLE, fhewing the quantities of water capable of being raifed at HUBBERT's mill, according to the different heads or falls, and according to different perpendicular heights to which it is required to be raifed.

Head or fall of water.		Perpendicular height to be raifed above the mill head.	Quantity raifed per hour.			Proportionable quantity taken to that of the river *Coln*, Feb. 23, 1766.
Feet.	Inches.	Feet.	Cube feet.		Hogfheads of 52 ale gallons.	
5	7	20	356	=	2517	$\frac{1}{30}$ full
9	7	20	585,3	=	4138	$\frac{1}{18}$ full
10	7	20	634	=	4482	$\frac{1}{16}$ fcarce
10	7	15	788,3	=	5573	$\frac{1}{13}$ fcarce
10	7	10	1024,8	=	7246	$\frac{1}{10}$ fcarce
10	7	$8\frac{1}{2}$	1125	=	7954	$\frac{1}{9}$ fcarce.

London, March 10th, 1766. J. SMEATON.

P. S. Four Hogfheads as above make a ton liquid.

CORN MILL at WORKSOP.

The REPORT of John Smeaton, Engineer, concerning the practicability of erecting a Corn Mill, to be worked from the farm-yard pond, at *Workſop Manor:*

THE fall from the ſurface of the farm-yard pond to the ſurface of the canal, in the new menagerie, is 9 feet 6 inches, which is a ſufficient fall for the erection of a mill; the principal difficulty, therefore, attending this affair, is to ſupply the ſaid pond with water, ſufficient to anſwer the intended purpoſe.

The quantity of water neceſſary depends upon the quantity of corn to be ground, which was ſtated to me at 10 loads per week, that is 30 *Wincheſter* buſhels.

The quantity of water neceſſary to grind one buſhel of wheat into flour, will grind five quarters of malt, ſo that ſuppoſing 10 quarters of malt to be brewed per week, the quantity of water that is neceſſary to grind 32 buſhels of wheat per week will diſpatch the whole buſineſs.

Now 3600 cube feet of water will, in this ſituation, be required to grind one buſhel of wheat, and therefore 115200 cube feet will be neceſſary to grind 32 buſhels; and this quantity, at leaſt, muſt be ſupplied to the farm-yard pond in a week.

	Cube feet.
The overflowing of the pond at *Steetly* amount to, per week, - - - - -	40019
A ſpring riſing ſomewhat below, but which, together with *Steetly* overflowings, may be brought to the farm-yard pond, - - - - - - - -	15120
The pipes from *Steetly*, at 5 hogſheads per hour, which they are ſaid to run, gives 1018 cube feet per day, $\frac{2}{3}$ of which I ſuppoſe will directly, or indirectly, come into the pond, amounting, per week, to - - - - - - - -	4751
The engine put in order, and the pipes repaired, as it now ſtands, will raiſe into the farm-yard pond per week, - - - - - - - -	24080
Total of the above, per week, - - - - - - -	83970
The aggregate of the quantities before mentioned, - - - - - -	83970
The quantity required, - - - - - - - - -	115200
Deficient -	31230

The

The power 83970 cube feet is ſufficient for grinding $23\frac{1}{2}$ buſhels, that is, beſides grinding 10 quarters of malt, it will grind $21\frac{1}{2}$ buſhels of wheat, or about 7 loads; but this is not ſuppoſed enough, though there is no allowance made for waſte.

Coldwell Spring, having been carefully levelled, has been found to riſe 6 feet nearly higher than the ſurface of the farm yard pond, when that ſurface was $9\frac{1}{2}$ feet above the canal of the *New Menagarie.*

The courſe for an aqueduct has alſo been traced out, and though it will be almoſt 2 miles in length, yet this ſpring may be thereby conducted, upon a ſufficient declivity, to fall into the farm yard pond.

Coldwell Spring being gauged in the month of March, 1766, then afforded 161280 cube feet of water per week, a quantity capable of grinding near 45 buſhels of wheat; ſo that here we ſhall have 46080 cube feet of water per week to ſpare, or to allow for waſte, and what the ſpring may afford leſs in dry ſeaſons; but as it is ſaid to be nearly the ſame in the drieſt ſeaſons as when it was meaſured, we may ſafely reckon upon the whole quantity as above ſpecified; nay, conſiderably more, becauſe the defects will be more than made up, by taking in the brook that runs by the *Coldwell Spring*, which, at the time of meaſuring, was nearly equal to the ſpring, and in the drieſt ſeaſon is ſaid to run half as much; but if we reckon it only $\frac{1}{3}$ as much, viz. 53760 cube feet per week, we ſhall then have a ſurpluſage upon the whole of 99840 feet per week, which is almoſt $\frac{7}{8}$ of the whole quantity found neceſſary.

Here, then, is a ſufficient ſource of power not only effectually to anſwer the preſent purpoſe, but others alſo that may occur, and which in ſo large a family, may, in all probability, be very uſefully applied.

As this ſpring is alone ſufficient to anſwer the end, it would hardly ſeem a queſtion which ought to be preferred; but as an aqueduct for *Coldwell Spring* will paſs through rocky ground, in one part at the depth of 15 feet, and which, at a medium, will hold nearly $\frac{1}{8}$ of a mile, this, with ſome other difficulties, particularly the carrying it up the north lawn from the road, which being ſuppoſed a running ſand, will be troubleſome to dig, and will otherwiſe require arching; thoſe impediments will induce a conſiderable extra expence; ſo that to overcome all probable difficulties, and to make the whole of proper dimenſions and ſtrength, will require the ſum of 400*l.* to be expended upon it.

The deficiency of the former aggregates may, however, probably be made good by taking in the brook laſt mentioned: the particular obſervation was not made at the time, but, from the nature of the thing, it muſt be ſuppoſed that the water of this brook may be intercepted at ſuch a level as to be conducted over the principal impediments that affect the *Coldwell* courſe, and conſequently can be carried into the farm-yard pond, together with the water from *Steetly*, &c. now, if we reckon, as before, upon $\frac{1}{7}$ of the *Coldwell* quantity for this brook in dry ſeaſons, we have 53760 to be added to the former aggregate of 83970, which together amount to 137730 cube feet per week, which affords a ſurpluſage of 12530. This, however, is but barely ſufficient to allow for waſte, even if all the quantities held out in ſummer what they have been ſuppoſed from obſervations at the ſame time as thoſe on *Coldwell Spring* were taken.

This aggregate ſcheme may probably be brought to bear for 150*l.* if not 200*l.* leſs than the *Coldwell* aqueduct; yet, as a material part of the ſupply depends on the performance of the engine, this, if out of order, will render the mill defective alſo. The certainty of ſucceſs, therefore, attending the *Coldwell* aqueduct, and the permanency of the benefits ariſing therefrom, as depending wholly on natural cauſes, being conſidered, as every other part of the work will be the ſame, whichever way ſupplied with water, it ſeems that the value of 150*l.* or even 200*l.* ſaved in the firſt erection will no ways counterbalance the ſuperior degree of certainty attending the other ſcheme, as well as the further advantages that may probably be drawn from a ſuperior ſupply of water.

A further and ſubſtantial argument for executing the *Coldwell* aqueduct is, that by means thereof the whole of the waters mentioned may be *united* at a ſmall addition of charge; ſo that by this means, excluſive of the engine, and after deducting $\frac{1}{8}$ of the whole quantity for waſte, we ſhall have remaining a neat natural power of 240564 cube feet of water per week, a quantity capable of grinding 66$\frac{3}{4}$ buſhels, that is, above 22 loads of corn, being more than double the power required; ſo that, after ſerving very uſeful and valuable domeſtic purpoſes, in paſſing from the farm-yard pond to the canal of the new menagerie, it will there furniſh a fine ſupply of water for the caſcade in falling from the upper canal to the lower.

I have mentioned 400*l.* as the probable expence of an aqueduct from *Coldwell Spring* to the farm-yard pond, which ſum is drawn from an eſtimate made from ſuch obſervations as have already been collected, and is intended to give the beſt idea of the expence that I can at preſent: and I alſo reckon that the mill-work, together with build-

ing,

ing, the alterations that will be neceſſary in the farm-yard pond, and the drain that will be neceſſary for conveying the mill's water to the canal of the new menagerie, will coſt 400*l.* more. If, therefore, it is not thought worth while to execute the ſcheme at the expence of 800*l.* I would not adviſe to proceed upon it; but if ſo, then I ſhall be ready to make ſuch further obſervations as the former have ſuggeſted, in order to make out a particular plan of the whole, from which a more exact computation may be drawn.

J. Smeaton.

Newcaſtle, May 12, 1766.

SPURN POINT LIGHTS.

DESCRIPTION of the Machine for fupporting the temporary Lights to be erected at the *Spurn Point*.

A B is the round pan, cage, or bafket of iron, wherein the coal fire is made, to be 18 inches diameter, and 18 inches deep for the great light, and 16 by 16 for the leffer light, a little tapering towards the bottom.

C D is the maft for fupporting the cage, at the height of 50 feet above the ground for the great light, and 35 feet above ditto for the leffer. The maft is hung up on an iron axis *E E* at the height of $22\frac{1}{2}$ feet above the ground, and confequently $27\frac{1}{2}$ feet below the center of the greater light, by means of which axis the fire-pan is brought down fufficiently near the ground to fupply the fame with fuel; the fire-pan turning upon an axis of its own or fwivel, fo as to keep it upright in every pofition of the maft.

F is the ftone, of fufficient weight with the butt end of the maft, to balance the fire-pan, coals and iron-work at the other end, that it may turn freely, and in moderate weather be hauled down and up by hand of one man by means of two ropes, one faftened near the upper end, the other at the lower end of the maft, the ftone to be hooped to prevent its fplitting.

G G is a roller with winches, to which the ropes aforefaid being refpectively applied with hooks for the more ready faftening to the ftaples in the roller, the maft will be managed in hauling down and up alfo by one man in the moft ftormy weather.

H H is a fixed piece of wood with a femicircular hollow, to which the lower end of the maft applies itfelf when in an upright pofition, and when neceffary is retained therein by an half circular keeper, plate, or clafp of iron.

a a the great axis of the maft, is fupported upon two upright pofts 22 feet 4 inches above ground, and 3 feet within ground, framed into groundfills at the bottom, and each poft braced in three directions; the feet of the braces to be framed into the groundfills, and all the bearings fupported by piles underneath, difpofed as per plan.

I K are the two upright pofts.

L M N

L M N are three braces belonging to the poſt *I*, and

O P Q are the braces belonging to the poſt *K*.

In order to keep the tops of the poſts at a ſtill more certain diſtance, the ends of the axis are to be finiſhed each by a knob, to lay upon the outſide of the bearing crutches or braſſes, which will hinder the tops of the poſts from flying out, and on the out ends of the knobs iron ſtuds are to be driven into the top of the poſts, which will keep them from coming together, the axis acting as a ſtretcher. The tops of the poſts are to be hooped, the more effectually to fix the work thereon, and covered each with an iron plate to defend them from the hot cinders.

R is a pulley in order to ſet the rope at a proper diſtance for hauling down the maſt by the windlaſs roll; this rope is to be annexed to about two yards of ſmall chain fixed at the point *b*; ſuch as is made for the ſmalleſt ſize of horſe traces, will be ſtrong enough.

S is an umbrella made of thin boards, to prevent coals, &c. from falling upon the perſon working at the roller, the pulley *R* is ſet at a diſtance in order that the rope for hauling down the maſt may have the better purchaſe upon it when upright; where note, that this rope being fixed to the maſt at *b*, when the pan is down, and the point *c* brought down to the point *e*, then the point *b* will come to the point *f*, and the tail of the maſt will be at the point *g*, and the line *G g* will be the direction of the rope when it begins to act from the roller upon the tail of the maſt, in order to hoiſt up the fire-pan, and ſet it upright.

N. B. The balance of the whole is to be ſo adjuſted, that when the pan is full of coals, the head of the maſt will be heavieſt, but when the fire is burnt low then the head of the maſt ſhall be lighteſt.

The ſame letters refer to the ſame thing in all the figures.

The meaſures ſet down in figures refer to the greater light, but the meaſures will be given for the leſſer light, by taking off the reſpective parts from the ſcale belonging to the leſſer, which will give every thing in proportion to their reſpective heights.

Directions for the ſmith.

It is to be obſerved that the fire-pan, with fork or crutch for ſupporting it, as well as all the iron-work at the maſt head, is to be made as light as poſſible, conſiſtent with the neceſſary

neceffary degree of ftrength; $1\frac{1}{2}$ inch diameter will be fufficient for the two branches of the fork near their joining, and tapered to $1\frac{1}{4}$ near the holes for the axis on which the pan hangs, the reft in proportion; the whole to be made as fhort as poffible between the top point of the wood of the maft and the axis, whereon the fire-pan hangs. It is alfo to be obferved that the fire-pan axis projects 6 inches on a fide beyond the ring, and that an iron ftrap be brought up from each fide the bottom of the pan, and connected to the ends of the axis, as fhewn in the front elevation, in order to prevent the axis from fagging by the heat of the fire. It muft alfo be obferved to make the round gudgeons of the fire-pan axis not above $\frac{7}{8}$ of an inch diameter in the round part, but the holes at leaft $1\frac{3}{8}$ or $1\frac{1}{2}$, and the gudgeons long enough that they may not jamb faft, or draw out by a little bending or fagging; one of the holes muft alfo be made to open in order to change the pan occafionally, as repairs may require.

c c is the fire-pan's axis.

d d the two traps from the bottom.

EXPLANATORY Remarks and Obfervations upon the defigns for building the Light-houfes upon the *Spurn Point*, as approved of by the Honourable Corporation of Trinity-Houfe, *Deptford Strond, London.*

No. 1. The general plan.

As the prefent variation of the compafs at the *Spurn Point* is not exactly known, in cafe it fhould be found to differ from that fuppofed in this plan, viz. 20 degrees wefterly, the direction of the light-houfes in refpect to one another are to be placed S. E. and N. W. by the compafs, and the windows, &c. of the buildings to be placed according to the true meridian.

No. 2. The fection and elevation of the great light-houfe.

The top of the ftone fetting or pitching of the foundation is herein fuppofed to be about 3 feet 6 inches below the general furface of the ground, from whence the height of 90 feet to the center of the lanthorn is taken; but as it is intended that the faid fetting fhall reft upon the bed of gravel or fhingle underneath the upper ftratum of fand, the depth

depth of the foundation may be a little varied, according to the depth at which the gravel is found, fo as to give the foundation a greater degree of folidity. The length of the piles may alfo be varied if they cannot be got down to the length fpecified, or in cafe they drive too eafily to that depth.

In the fection, *A* fhews a pipe or paffage-hole for the facks of coals, from the coal-vault to the lanthorn, to be drawn up by the machine *B*, which alfo ferves for drawing up the facks of coals that are brought in carts from the waterfide into the door *F*, by means of the fmall gibbet at *C*, from whence they are to be poured down into the vault by the trap-door *D*, when filled too high, to open the door *E*.

G is a pipe for bringing down the afhes.

N. B. The jaumbs of the doors are fuppofed in the eftimate to be of ftone.

No. 3. Section of the lanthorn pipe room.

The receptacle for the afhes, both bottom and fides, for $4\frac{1}{2}$ feet in height, are fuppofed to be compleatly lined with plate iron of $\frac{1}{10}$ of an inch thick, to prevent the hot cinders and afhes from burning the wooden cafe; the door muft be made as tight as poffible.

Between the ftone covers of the air tunnels *a a* other ftones are to be introduced, though not fhewn on the outfide, fo as to compleat a circle of ftones, which are to be well crampt together, in order to form a chain courfe for the fpringing of the brick arch thereupon.

B B are large bellows, to ferve when the wind does not blow ftrong enough.

C is a tunnel and afh-pipe, for the fpeedy conveying the afhes and cinders to the outfide of the bottom of the houfe, when the receptacle is emptied, as it ought to be every day.

D, air-holes in each face of the lanthorns, to be ftopped or unftopped with fliders, in order to prevent the lanthorn from fmoaking.

The hearth and floors of the lanthorn and balcony, together with the bafement of the lanthorn, to be of ftone; the roof and chimney to be of four-inch *Elland* edge flags, properly mitred together; the balcony rails to be of iron.

No. 4.

No. 4. Shews the plan of the lanthorn floor, and an horizontal ſection through the air pipes,

Where, in the plan, *A* is the paſſage or door-way up into the lanthorn, *B* the cover for the ſack-hole.

At *a* is a hole for the rope to go down to the machine for hoiſting the ſacks, to be returned over pullies in the upper part of the lanthorn, ſo as to anſwer to the middle of the ſack-hole.

b is a hole for a rope from the bellows, which, being returned in like manner over pullies, may go down into the pipe-room by the hole marked *c*, ſo as occaſionally to be blown there as well as in the lanthorn, in caſe that in ſummer time the lanthorn ſhall prove too hot.

In the ſection, *C* ſhews the place of the ſack-hole.

d is a multiplying wheel and axle for working the bellows with ropes inſtead of a lever, which in this place would be inconvenient, eſpecially when the perſon working them is in the lanthorn, as in general he is ſuppoſed to be.

N. B. The bellows are ſuppoſed to be made ſquare, in the way of organ bellows, but with neat's leather, and nailed together.

e ſhews the flat of a ſlider, and *g* is the ſame in its proper poſition; each air-pipe to have one, in order to open any of them at pleaſure, and regulate the force of the wind when too ſtrong.

N. B. In order to give the wind its full force, 2 or 3 of them to the windward to be open, and all the reſt cloſed, and when the bellows are uſed, to be all cloſed.

No. 5. Plan and upright of one of the window-frames for the lanthorn,

Wherein the upright *A A* ſhews two of the upright pillars or ſtanchions to be of caſt iron.

a a the ſell, and *b b* the plating of ſtrong iron bars, by which the pillars are connected; the window-frame is to be of wood, but ſtrengthened by a bar of iron, laying within the middle horizontal bar, and ſcrewed thereto, as repreſented in the plan at *c c c*.

No. 6.

No. 6. The section and elevation of the small light-house.

As this light-house is to he constructed upon similar principles with that of the great one, and the difference of dimensions being assigned by this general design, it is presumed that a more particular description of the parts will be unnecessary, when reference is had to what precedes and succeeds relative to the great one.

No. 7. Design for one of the ten iron stanchions that form the windows, and support the roof of the lanthorn, drawn at large.

This, with reference to what is explained concerning No. 5, will be sufficiently clear from what is upon the face thereof.

No. 8. Plan and section of the fire-cage and hearth.

This is supposed to be sufficiently explained with what is upon the face thereof.

No. 9. Plan of the foundation.

Upon the outward and inward circles of piles a kirb of wood is to be nailed down upon their heads, which are first to be cut level; but before the kirbs of wood are fixed down, the whole intermediate space between the piles is to be pitched or set with *Elland* edge setters, of 9 inches in depth, set edgeways, in the manner the streets are paved about *Hallifax*; those are to be well rammed down with a two-man rammer in in the manner of a pavement, taking care that those setters that will be covered by the kirbs may be somewhat fuller than the pile heads, that the kirbs may take their bearings equally upon the setters as upon the piles: this done, the joints must be run full of grout, made of lime and sand made fluid with a proper quantity of water, which done the brick-work must be carried on thereupon as shewn in No. 2.

No. 10. Plan of the vault or basement story.

This is a plan of the vault at the top of the plinth or set-off above ground; the rest will sufficiently appear by reference to No. 2.

No. 11. Smith's shop floor and store-room floor.

Wherein the smith's shop floor *A* shews the great door, *D* the projecting landing-place, *E* the gibbet, *F* the machine or winch for hoisting the coals, *B* the hatchway for shooting the coals down into the vault, which being in the middle will be equally

diftributed, *C* the hatchway for the facks to go up into the lanthorn, anfwerable to the fack-hole or pipe defcribed No. 2. *H* fhews the place of the afh-pipe.

In the plan of the ftore room floor, *G* is the fack-hole, and *H* the afh-pipe, the eaft and weft windows blank.

N. B. The doorway or hatchway had better be nearer the wall, as well in this as in the floors above.

No. 12. The dwelling-room floor and chamber-floor.

After what has been remarked on No. 11. it is only neceffary to obferve that there being two oppofite chimnies in the dwelling-room, they may be ufed the one or the other as beft fuits the wind; in the chamber-floor the north and weft windows are fuppofed blank.

No. 13. The upper chamber-floor and pipe-room floor

Will be fufficiently explained from what has been already remarked, the north and weft windows in the upper chamber being fuppofed blank as in the chamber below, the pipe-room windows all open.

J. Smeaton.

The foregoing explanatory obfervations were fent to *London* for the approbation of the Corporation of Trinity Houfe, a copy of which was by them returned, in order to be returned to Mr. Thompson in their Common Seal, to which was fubjoined the following.

" Trinity-Houfe, *London*, March 21, 1767.

" Thefe explanatory remarks and obfervations upon the defign or plan of the two new light-houfes to be erected at the *Spurn Point*, the Mafter, Wardens and Affiftants of the Corporation of Trinity Houfe of *Deptford Strond*, do hereby, under their Common Seal, approve of, and do appoint the fame to be carried into execution, purfuant to the act of Parliament paffed in the fixth year of his prefent Majefty's reign.

By order of the faid Corporation,

Charles Wildbore, Clerk."

ESTIMATE

ESTIMATE of the expence of building two Light-houſes, with proper conveniencies, upon the *Spurn Point*, as deſigned by JOHN SMEATON, Engineer, from the orders and directions of the Honourable Corporation of Trinity-Houſe of *Deptford Strond*.

Eſtimate of the great Light-houſe.

				£.	s.	d.
To caſting, piling, and ſetting the foundation, as per plan,				123	10	0
To brick-work in the building,				482	13	1
To ſtone-work in ditto,				201	14	0
To carpenters work in ditto,				249	3	4
To iron-work in the lanthorn,	100	14	4			
To ditto in the balcony rails,	65	6	8			
To ditto in the fire-place, with 2 cages,	30	8	0			
To ditto in the building,	62	15	4			
Total of iron-work,				259	4	4
To plumbers-work, covering the balcony floor with lead,	56	19	3			
To ditto in ciſtern and pipes to bring rain-water from the roof,	15	6	0			
Total of plumbers-work,				72	5	3
To glazing the windows of the rooms,	5	0	0			
To ditto in the lanthorn,	12	5	0			
Total of glaziers-work,				17	5	0
Great light-houſe,				1405	15	0
The great light-houſe, as per eſtimate,				1405	15	0
The ſmall light-houſe, eſtimated at $\frac{3}{4}$ of the expence of the great one,				1054	6	0
The ſtone platform between the two houſes,				90	0	0
The brick wall round the greater light-houſe, 30 yards diameter, with carriage and ſmall door, and capped with ſtone,				118	12	0
Ditto round the ſmall light-houſe, 27 yards diameter, but being more expoſed, eſtimated at ditto,				118	12	0
				2787	5	0
To the above allow for accidents, contingencies, and difficulty of ſituation, 10 per cent. upon the whole,				278	15	0
				3066	0	0

N. B. Nothing is allowed in the above eſtimate on account of ſupervisal.

London, February 21, 1767. J. SMEATON.

This estimate was authenticated by the board, under their common seal, and with the following testimony:

" This Estimate of the expence of erecting two new light-houses on the *Spurn Point*, the Master, Warden, and Assistants of the Corporation of Trinity-House of *Deptford Strond*, do hereby, under their common seal, approve of, and do appoint the same to be carried into execution, pursuant to the act of Parliament passed in the sixth year of his present Majesty's reign.

By order of the said Corporation,

CHARLES WILDBORE, Clerk."

Trinity-House, February 21, 1767.

(Duplicate. C. W.)

ADDITIONAL Remarks and Observations, touching the construction of the Light-houses upon the *Spurn Point*, as approved of by the Honourable Corporation of Trinity-House, *Deptford Strond*, *London*.

Design No. 1. Being the general plan.

It is mentioned that the light-houses are to be placed at the distance of 300 yards center and center, and in a direction S. E. and N. W. by the compass, in respect to each other; to be joined by a platform of stone, the construction of which I proposed to be as follows:

To be composed of *Elland Edge* natural-faced flags, 2 feet in breadth and 4 inches thick; to be supported by a pavement or setting of brick on the edge, and 3 bricks lengths wide, to be well beat down with a paviour's rammer, the ground being first levelled and consolidated by ramming; the hand-rail to be 3½ inches square, supported by posts of 4½ inches and 6 feet long, set in the ground, so that the rail may not be more than 3 feet above the surface of the flagging. This timber is supposed to be of *Riga* fir.

The circular brick wall round the great light-house, said to be 30 yards diameter, that is, out and out, I propose to found at the depth of 3 feet, or thereabouts, below the mean surface of the ground, but if at a less depth, a stratum of gravel can be found tolerably compact to found upon it. The bottom, when opened, to be consolidated

lidated by ramming, and the firſt ground courſe to be 3 bricks length broad, ſet upon the edge, and driven down like a pavement; then two courſes upon it to be laid flat-ways, as common, in mortar, of $2\frac{1}{2}$ bricks wide; then to be carried up of two bricks till a foot above the ground; then to be raiſed to 8 feet 8 inches high above ground, and to be capped with ſtone 4 inches thick: this, if the undertaker chuſes, may be of *Elland* edge flagging, with the natural faces, but hewn true to a joint and regular border; or with any other kind of ſtone, ſuch as uſed about the light-houſes, that will bear the weather: the capping to project about 2 inches on each ſide, and to drip towards the outſide, to be laid on with mortar made of lime from *Barrow*, in *Leiceſterſhire*, or any other lime of equal quality for water-works. The body of the wall to be built with lime from *Houghton*, near *Caſtleford*, *Yorkſhire*, or any other of equal quality.

The ſmall light-houſe circular wall to be founded as the former, but the mortar courſes on the 3 bricks length on edge ſetting; to be raiſed $2\frac{1}{2}$ bricks thick to 1 foot above ground, and then 2 bricks to 8 feet 8 inches above ground, and covered with 4 inch capping like the former, without any projection on the outſide, and about 2 inches within, but laid ſo as to drip outwards, the outſide brick breadth to be walled, and the capping to be laid on with *Barrow* lime, and the reſt walled with *Houghton*, and both walls to be grouted or run with liquid mortar every four courſes.

The area of theſe two courſes between the light-houſes and the out-walls ſhould be paved with good bowlers, ſo as to reſiſt the wheels of carriages carrying coals. This article has not been particularly conſidered in my original eſtimate, otherwiſe than in the articles of contingencies.

Deſign No. 2. Being the ſection and elevation of the great Light-houſe.

The external and internal circle of piles in the foundations are, as drawn, intended to be 10 feet long, and 10 inches diameter at the heads, and the internal piling of 9 feet long, and 9 inches diameter at the heads; but both theſe dimenſions to be varied according as the ground proves on trying it with piles: the piles here ſuppoſed are of oak, elm, beech, or alder, but may be of *Riga* fir, or any other kind of red wood fir of equal quality for duration under ground, in which caſe, if ſquare 9 inches will do for the kirbs, and 8 inches ſquare for the internal piling, the length being ſuppoſed the ſame as before.

The thickneſs of that part of the ſhell of brick-work marked 2 feet, is ſuppoſed $3\frac{1}{2}$ bricks, and that marked 1 foot 7 inches of 2 bricks thick; the bricks in the north being

being made larger than those in the south, it was supposed they might probably in walling make those thicknesses specified, but at the same time it was not proposed to have bricks made on purpose, but to be walled with the common size of bricks usually made in that part of the country, but they should not be less than the statute thickness for *London*; and, N. B. wherever a difference in the dimensions of the bricks, the thicknesses assigned to the several parts cannot exactly tally; it is the outside measure which is to be preserved, unless particularly directed to the contrary. The sort of bricks proposed to be used is what in the north are called water-bricks, in contradistinction to stock-bricks, but those to be particularly hard and well burnt.

It was proposed to build the whole with *Houghton* lime, or other good stone lime of equal quality; but I am of opinion, that, considering the exposure of the situation, it will answer a better purpose to have the outside bricks in breadth walled with *Barrow* lime, leaving the undertaker to make use of what lime he chuses for the internal parts of the wall, being stone lime good in its kind, and well tempered; and that it will be better to allow the undertaker whatever difference there may be in the value of both sorts together, if any, when used instead of *Houghton* lime for the whole, than that this precaution should be neglected. The whole of the inside to be walled fair, and to be grouted at every fourth course. The undertaker to be allowed to use, if he pleases, either sea water, or such as can be obtained by digging a well upon the spot, as he shall chuse; and to prevent any damp in the dwelling-room it will be proper to be stoothed, lathed, and plaistered, (the plaister being made up with fresh water) which will be a far more effectual defence against damp, than any difference that can arise from the quality of the water in the out-walls, having found that good mortar binds as well with salt water as fresh.

N. B. This article of stoothing and plaistering was not considered in the original estimate.

In regard to the stone-work, all the parts that require large flat stones will be best supplied from *Elland-Edge*, or from *Cromwell Bottom* quarries, which are of the same quality; but in regard to the stone-work for door-cases, window-sills, steps, the air-pipe mouths, and girdle stones, to compleat and cramp that course together, with the mutules and facia composing the balcony floor and basement of the lanthorn, as there are a number of good quarries in the neighbourhood of *Aire*, *Calder*, and *Dun*, as well as at *Sunderland*, which afford the proper materials, the undertaker should have the choice of getting them where he can serve himself with most advantage, being obliged to furnish good strong stone, and such as will endure the weather.

Instead

Inſtead of lintells on the inſides of the doors and windows, they are propoſed to be arched with brick.

The timber every where to be made uſe of is ſuppoſed to be the beſt *Riga* fir, or other red wood fir of equal quality, for the reſpective purpoſes, except where the ſort of wood is particularly expreſſed to be of a different kind. The doors between room and room are propoſed to be trap-doors, and the aſcent between room and room to be ſtrong ſtep ladders of equal width with the door-ways, the ſides to be at leaſt 8 inches by $1\frac{1}{2}$, and the ſteps not to exceed 8 inches riſe, and the ladders not to ſtand ſteeper than an angle of 45 degrees where the place will properly allow it.

The windows of the rooms to be of clean well ſeaſoned *Engliſh* oak; they are deſigned to be ſimply a frame, whoſe outſide circumference is 3 inches by 2, and the inſide bars of ſtuff $1\frac{1}{2}$ by 2 inches; they are to be fixed up againſt a check made by the projection of the outward bricks, and faſtened by a pin, ſo that the whole frame may be taken out at pleaſure, in order to air and ventilate the rooms, when occaſion ſhall require, and the weather admit: there is a ſmall error in the original drawings, in regard to the manner of forming the window-ſole ſtones, wherein the check is repreſented on the outſide, and that, for the ſake of keeping out and venting the wet, ought to be within; and as this matter cannot be ſo eaſily deſcribed in words as to prevent all uncertainty, I have added a drawing, intituled No. 14, wherein the particulars are expreſſed more at large. The glazing of all the room windows ſuppoſed to be of common glaſs; the clear opening of all the windows, when the frames are out, is 2 feet wide by 2 feet 6 inches high, the pipe-room windows excepted, which are to be 2 feet wide by 2 feet high.

Their number will be as follows:

In the ſmith's ſhop,	E. W. and N.	3	All the reſt blanks, with arches and ſole ſtones to preſerve the regularity on the outſide, and to be opened afterwards, if need ſhould happen to require.
In the ſtore-room,	N. and S.	2	
In the dwelling-room,	E. W. N. and S.	4	
In the chamber,	N. and S.	2	
In the upper chamber,	N. and S.	2	
In the pipe-room,	E. W. N. S.	4	

Deſigns, being No. 3 and 4, being ſections and plans of the lanthorn and pipe room.

Upon No. 3 I obſerve, that the windows may, with more advantage, be placed two courſe of bricks higher, or nearer the pipe mouth-holes, that above the propoſed lining with plate iron; of the receptable for the arches, it will, for further ſecurity, be proper

to

to line the whole infide of the wood-work, compofing the upright tube, with double tin-plate, and to extend the fame the breadth of a tin-plate within the air-pipes.

The ftones mentioned to be laid between the pipe-mouth ftones, marked *a a*, in order to form a chain courfe, are fuppofed to lay upon the fame bed as the cap-ftones of the air-holes, and to reach to the outfide, wanting only one brick's breadth, that is, they will be 1 foot 6 inches up and down, and 1 foot 9 inches infide and out, at the extreme breadth: the whole of this courfe to be of ftone of a firm quality, and double cramped upon the upper furface with cramps of 2 inches broad, $\frac{1}{2}$ an inch thick, and 14 inches long, and to be put in hot, and buried in a body of lead: the facia in like manner, compofing the balcony floor, to be cramped with a double fet of cramps fixed in the fame manner, the joints thereof to be filled, and very carefully pointed with cement made of equal parts of *Barrow* lime, and pozzolano or fmiths forge fcales: the aperture or crown of the arch to be fet round with an arched circle of ftone of 9 inches thick, and the height of a brick's length.

The top of the balcony rails to be at leaft 3 feet 6 inches above the floor, and 3 feet high in the bars, which are to be of $1\frac{1}{4}$ inch thick, and 100 in number in the whole circle, and the upper and under circle connecting them to be 3 inches broad and $\frac{1}{2}$ inch thick; this circular railing to be fupported by 20 ftuds leaded into the facia, and turned with a crutch at the top to take the lower circle of the railing without any other fixing thereto than the weight of the railing.

The lower fell of the lanthorn frame to be fet in putty, made of white lead and oil, the upper fell of ditto to be covered with a kirb of wood bolted down, to be cut to a proper bevil for fupporting the ftone roof; this kirb to be oak; the chimney to be compofed of five pieces, and to be hooped with two ftrong hoops round the whole, of 3 inches head and $\frac{1}{2}$ thick.

N. B. It will be neceffary to cut a fmall half circular grove under the facia, to prevent the wet from following the under fide to the wall. The door in the balcony from the lanthorn to be of oak.

Defigns No. 5. and 7. The former being a plan and upright of one of the window-frames for the lanthorn, and the latter a defign for one of the 10 caft iron ftanchions that form the windows, and fupport the roof of the lanthorn, drawn at large.

Upon

Upon which I have to remark, that the window-frames are ſuppoſed to be made of the beſt clean dry *Engliſh* oak, put together with white lead and oil, and glazed with the beſt crown glaſs, each frame to be fixed in place by 32 ſtrong wood ſcrews, and by two ſmall bolts, that take the croſs bars; and that all the iron-work, together with the ſcrews, bolts, &c. and window-frames, are to be put together with white lead and oil, the whole being firſt painted twice over when tried together, and afterwards two coats when fixed in place.

Deſign 6. being a ſection and elevation of the ſmall light-houſe.

Whatever has been or ſhall be obſerved regarding the great light-houſe, that will apply to the ſmall one, is to be applied thereto, except what is particularly ſpecified by the deſign or in writing to be otherwiſe.

The piles under this light-houſe are ſuppoſed to be of the ſame dimenſions, and in number proportionable to the circumference of the circle of their reſpective baſes, the ſtone ſetting between the piles to be of equal depth and ſolidity.

It now ſeems more eligible to make the room above the vault a ſtore-room, and to put the two fire-places into the room above, in order to convert it into a dwelling-room, to be ſtoothed as the other.

The floors to be twelve-inch beams, and common joiſts 4 by 5.

The height of the mutules are intended to be 6 inches, and the height of the facia 12 inches at the edge, and to riſe ½ an inch at the lanthorn, to be double cramped, as alſo the chain courſe at the air-pipe holes, as in the great light-houſe.

The number of windows in the ſmall light-houſe as follows:

The room above the vault	N.	1	The reſt walled blank, with arches and ſole ſtones, as in the great light-houſe.
The chamber and dwelling-room	E. W. N. S.	4	
The pipe-room - - -	E. W. N. S.	4	
Open windows		9	

N. B. The windows of the rooms and pipe-room to be of the ſame dimenſions as the great light-houſe.

This light-houſe is propoſed to be furniſhed with bellows of a proportionable ſize to thoſe of the great light-houſe; but I apprehend the bellows in both light-houſes may be omitted till it be ſeen whether the fire may not have a ſufficient draught in calm weather by ſetting all the air-pipes open, without working the bellows, for unleſs they are neceſſary they may be cumberſome, and may at any time be added.

The ſack-hole pipe is repreſented as broken off at top, not only in this elevation, but in that of the great light-houſe, the part of the arch wherewith it unites being that ſuppoſed to be removed from before the eye, but in reality thoſe pipes are to be made to unite with the proper opening through the arch for the ſack to paſs through up into the lanthorn.

The balcony rails are, as per deſign, to be the ſame height, and the iron of the ſame thickneſs, as for the great light-houſe, but the number of bars to be only 80, the height of the lanthorn in the glaſs to be the ſame as the great light-houſe, and the caſt-iron ſtanchions the ſame.

Deſign No. 8. is a plan and ſection of the fire-cage and hearth, upon which I have to remark, that it ſeems more eligible that the brick-work that ſupports it ſhould be raiſed about a courſe higher, in order to bring the lower ring of the cage even with the top of the ſtone baſement of the lanthorn; and N. B. the ſpaces between the eight pillars that ſupport it are to be cloſed with milled plate iron $\frac{1}{8}$ thick, one ſide being made to open with hinges and a latch like a door, in order to clear the grate.

Deſign No. 9. is the plan of the foundation; to which I ſhall add, that the kirbs, being 10 by 6, are to be of oak, elm, or beech, but that the internal piles are, as already mentioned, to be varied in number, ſize, and diſpoſition, according as ſhall appear upon trial by driving after the ground is opened: the foundation here ſpecified being ſuch as appeared proper upon ſuch trials as were made in preſence of the gentlemen of Trinity-Houſe, *Deptford Strond*, when I had the honour of attending them there.

Deſign No. 10. being a plan of the vault or baſement ſtory, there is nothing to add but that the dotted lines upon the points E. W. N. and S. ſhew the places of four air-holes to ventilate and give light into the vault.

N. B. I apprehend it may be more eligible to make the entry-doors to open internally.

Deſign

Deſign No. 11. is a plan of the ſmith's ſhop; floor to be flagged with natural-faced *Elland-Edge* flags, well jointed and laid; the two openings *B C* having a rebate cut round them, are to be covered with looſe lids (with a ring in the middle) made of a double thickneſs of oak plank of $1\frac{1}{2}$ inch clinched together; the middle hole, though marked 3 feet, need not be larger than the other, viz. 2 feet 6 inches.

The gibbet *E* to be of oak, and to have a rope of a proper length, with guide pullies for hoiſting ſacks of coals out of the carts, ſeparate from the rope for hoiſting coals to the top of the houſe, each rope to remain reeved, and ready to be applied to the barrel of the machine as occaſion ſhall require; the machine to be made with an iron wheel and pinion compleat *.

In the ſtore-room floor the door-way, upon the whole, may, in this as the reſt, remain in the place ſhewn in the plan; the beams to be 14 inches ſquare, the joiſts 4 by 8, and the joiſts on each ſide the door-way to be 6 by 8.

Deſign No. 12. contains plans of the dwelling-room and chamber-floors, wherein it is to be remarked, that the girders lay alternately croſs of each other.

In the dwelling-room is propoſed two fire-places, that either may be made uſe of as the wind blows; the funnels are to be carried up in the walls, and laſtly carried to the outſide, and to be terminated like a cup by corbelling or overſetting the bricks near the top; thoſe funnels to terminate at or about the height of the middle chamber-floor.

Before the chimnies are to be two hearth-ſtones of *Elland-Edge* natural-faced flags of $2\frac{1}{2}$ feet broad at leaſt, and 5 feet long; each fire-place to be furniſhed with a grate or range ſet in ſtones that will bear the fire; the girders of the dwelling-room floor to be 13 inches ſquare, and thoſe of the chamber 12 inches ſquare; the joiſts the ſame as the ſtore-room.

Deſign No. 13. is added to ſhew the relative ſizes and diſpoſition of the floors, and ſeems to require no further directions than what is upon the face of it: the girders of the upper chamber-floor being 12 inches ſquare, and thoſe of the pipe-room 13 inches ſquare; the common joiſts being 4 by 8, and the door-way joiſts 6 by 8, like all the other floors.

* The bellows and anvil are not ſuppoſed to be furniſhed by the undertaker.

The iron-work for hanging the doors as follows:

The double doors for carriages to be 9 feet clear width in each of the circular walls, to be hung upon well-made loops and crooks, not lefs than 8 lb. loop and crook together; the crooks to be leaded into ftone inlaid in the wall, and the loops to be fixed to the doors with fmall fcrew bolts. Thefe doors to be made with proper bars and faftenings to hold them open and keep them fhut. The fmall doors in the circular wall $2\frac{1}{2}$ feet clear width, anfwerable to the platform from houfe to houfe, to be hung with loops and and crooks of 5 lb. per loop and crook, and leaded into ftone with proportionable latches and bars. The vault doors to be hung upon the fame loops and crooks as thofe fpecified for the double doors of the out-walls, and fixed in the fame manner, with each two bars or bolts of 4 lb. each bar, and a lock to each door. The entry doors to have the fame loops and crooks as fpecified for the fmall doors in the circular walls, with each a lock, bolt, and latch of proportionable ftrength. The crane doors and balcony doors to have loops and crooks the fame as the out-wall fmall doors, with each a bolt of proportionable fize. The trap doors to the floors to be hung upon good HL hinges of at leaft 10, or T hinges of 13 inches, with one bolt of a proportionable fize.

All the doors to be plain batten doors, except the two entry doors, which are fuppofed to be done with fomewhat more neatnefs; all the out-doors to be of whole deal, and the trap-doors, on account of lightnefs, not lefs than $\frac{7}{8}$ thick when worked; all the doors and floors to be planed and fhot clear of fap, and to be lathed, tongued, or rebated together.

The article of painting was not confidered in the original eftimate otherwife than by the general article of contingencies; but it is propofed that all the outfide wood and iron work be painted with at leaft two good coats, which has not been already fpecified to be done with more; all the fafh-frames with white lead and oil, all the iron-work with white lead and oil made of a dark lead colour with lamp black, and the doors, &c. with good red priming.

In refpect to the lead covering of the balcony-floor (which was propofed to be done with lead of about 10 lb. to the foot) in cafe the joints are well cemented, as has been fpecified, I am of opinion, on reconfidering this article, that the lead may be omitted; and as the roof of the lanthorn and floor of the balcony will be greatly annoyed with foot and coal-duft, infomuch that it is probable but very little of good frefh water can be collected, it feems that the lead pipe and ciftern may alfo be omitted, and in lieu thereof that the undertaker furnifh each light-houfe with a good ftone trough or ciftern, to hold

at

at leaſt two hogſheads each, properly ſupported on brick-work, with a cover to each, for depoſiting ſuch freſh water as ſhall be brought from the main land; and alſo to cover the hips of the lanthorn roofs with lead; and as in the above articles of lead-work to be omitted, there will be a deduction of 72*l.* 5*s.* 3*d.* in the original eſtimate upon the great light-houſe, and 54*l.* 3*s.* 11*d.* upon the ſmaller one, it may be reaſonably expected that thoſe ſums, making together 126*l.* 9*s.* 2*d.* will fully compenſate every article of additional expence which was not fully conſidered in the firſt eſtimate, or has on this reviſal been ſuggeſted.

I beg leave further to obſerve to this Honourable Corporation, if they can admit both the light-houſes to be ſomewhat altered from the places marked out in the plan No. 1, that is to go upon the ſame line about 80 yards more to the N. W. in order to bring the ſmall light-houſe more out of the way of the ſeas in time of ſtorms at high water, that it would be a means of preventing unforeſeen expences in the protecting the out-works of the ſmall light-houſe from the effects of ſuch inſults; and this appeared to me the more deſirable when I was upon the view of the temporary lights (in order to make an eſtimate thereof) as ſome derangements had happened to the platform and coal-yard near the ſmall light-houſe by a ſtorm happening at a great tide.

Auſthorpe, May 9, 1770. J. SMEATON.

The REPORT of JOHN SMEATON, Engineer, concerning the ſtate of the Light-Houſes building at the *Spurn Point*, under direction of the Trinity Houſe, *Deptford Strond, London.*

THE beginning of December laſt I was at the *Spurn Point*, in order to view the ſtate of the works carrying on there by Mr. TAYLOR, and found that the ſhell of the leſſer light-houſe was erected, and the lanthorn compleatly framed, and ſet up and ready for receiving the glaſs, all the naked floors in, and the hearth erected ready for receiving the grate; ſo that, excluſive of the balcony-rails, the glaſs, and inſide finiſhing, this light-houſe may be conſidered as erected.

The foundation for the circular wall round this houſe has alſo been for ſome time laid, and brought even with the ſurface of the ground.

The

The great light-houſe was alſo then raiſed five courſes of bricks above the ſecond timber floor; both which floors were in place, and the arch of the coal vault compleated, as alſo the ſtone ſtairs up to the ſmith's room floor.

The height of the greater light-houſe above it's foundation was then 44 feet 6 inches, and near 40 feet above the ground, which is ſomewhat irregular.

The bricklayers were then at work, and as it is ſaid there is ſeldom any froſt at the *Spurn Point*, it is probable that the brick-work done in winter may become even more ſolid than what is done in ſummer. The brick-work of both houſes is ſomewhat rough, but as Mr. TAYLOR ſeems very careful to have the courſes properly grouted, or run with liquid mortar, I have no doubt of the firmneſs of the work, and which, at a very little diſtance, has all the effect upon the eye that can be expected.

On examining his ſtores upon the place, I found all the timber floors prepared, together with a large quantity of boards planed and tried up ready for the floors, doors, air communications, &c. ſo that I apprehend, taking the work done and preparations upon the place, as they appeared upon my view the beginning of December laſt, in part of the whole, that 1000*l.* in addition would compleat the two light-houſes according to the contract.

Mr. TAYLOR applied to me to have his extras ſettled, that is, the additional piles in the foundations, and depth of building, occaſioned by the foundations being laid lower than the plan, and ſome other things that will be due to him; but I told him that as there might yet be others before he had done, it might be as well to ſettle all the extras together; to which he did not object.

Mr. TAYLOR has made a greater progreſs between the laſt and the former viſitation than in any former period, and, if not cramped for men or money, I ſhould expect to ſee the light-houſes compleated for uſe in the courſe of the preſent year.

The variation of the *Point* is become ſtill more favourable to the preſent ſituation of the buildings than in my laſt repreſentation.

Mr. TAYLOR remarked to me a new ſand that the ſea appeared to break upon at low water, being due eaſt from the leſſer light by the true meridian, and at about a mile's diſtance; this I remarked to ſome of the gentlemen of the Trinity Houſe on my return to *Hull*, on ſuppoſition they would more circumſtantially inform themſelves, and acquaint this Honourable Board therewith.

London, 29th March, 1774. J. SMEATON.

REPORT upon the Lower Light at the *Spurn Point*, by JOHN SMEATON, Engineer.

FROM a view of the works at *Spurn Point*, taken the 25th of April, 1776, it appears to me, that ſince my repreſentation, by letter of the 22d of January laſt, the beach has conſiderably increaſed, not only in breadth but in height, and not only in the frontage of the low light-houſe and low temporary light, but for half a mile at leaſt coaſtwiſe towards the north eaſt.

Since then a cargo of *Hazlecliff* ſtone has been depoſited at the foot of the low light-houſe, upon the bricks reported to have been there depoſited in the ſaid letter, none of which appear to have been ſtirred from their place; but as the cover of *Hazlecliff* ſtone is not fully compleated, I have now ordered a further quantity, in order to compleat the ſame. A great part of both bricks and ſtone are buried in the beach, that a more favourable courſe of wind and tides have brought before the work as above mentioned; ſo that, from the above ſtate, it appears, that as things have taken that favourable turn that was wiſhed, and hoped for as very poſſible, the low light-houſe and low temporary light are not now in the imminent danger that they appeared in in January laſt; and as there is now a greater appearance of probability that the lower light-houſe may become and continue ſerviceable for ſome years to come, I am of opinion, that the beſt way to turn the work out of hand, and to give it the beſt chance of continuance, will be to rebuild that part of the circular wall that the ſea has taken down, and, to give it a greater depth and dimenſions than before, to make good the ground taken away in the court-yard; that will then again be incloſed ſolid with *Hazlecliff* ſtone, and alſo to depoſit a quantity of *Hazlecliff* ſtone round the circumference of the new wall outſide, in the ſame manner as is now done round the foot of the building; and laſtly to conſtruct ſome grynes of faſcinery, or ſtake and rice work, upon the beach, on both ſides the building, in order to catch and detain the beach, in a manner ſomething like what is practiſed upon the coaſt of *Suſſex*, in the frontage of *Romney Marſh*, &c. This is what, from circumſtances turning out favourable for the preſent, appears to me to be now adviſeable. Yet the opinion will remain valid that is particularly expreſſed in the 7th, 8th, 9th and 11th paragraphs of the ſaid letter of the 22d of January, and confirmed by the ſketch of the gradual changes made in the *Spurn Point* ſince and including the year 1766, remitted in my letter of the 24th of January, viz. that the whole coaſt for ſeveral miles being in a conſiderable ſtate of waſte to ſeaward, the ſandy beach compoſing the *Spurn Point* muſt follow it, and conſequently the ground being taken away behind the light-houſe, it will be left an iſland, and therefore indefenſible, but at much greater

greater expence than that of building a new houſe, even of the ſame conſtruction; but that, conſidering the fluctuating ſtate of the coaſt to ſeaward, that it ſeems more adviſeable to exhibit the lower light, whenever the preſent one ſhall fail, by means of a *machine light-houſe,* built upon the ſame principle as the preſent temporary high light, and that by way of proviſion for the conſtant exhibition of the lights, for the benefit and ſafety of navigation; that, in the mean time, the preſent large temporary light machine (as ſoon as thoſe lights are ordered to be ſtruck) be removed into the line as near the low light-houſe as ſhall appear convenient. This is the general ſenſe and meaning of the paragraphs in the letter above referred to, and which ſtill appear to me equally neceſſary now as then appeared; but I now beg leave to add, that if the Honourable Board of *Trinity Houſe, Deptford Strond,* ſhall think proper to order the rebuilding the circular wall, and the defences or out-works above mentioned, that it will then be impoſſible for the ſea to render the light-houſe unſerviceable ſo ſuddenly as not to give time to do ſome buſineſs. If it ſhould be liked better, the large temporary light-machine may be taken down, repaired, marked ready for putting up again, and ſafely depoſited under cover, ready to put up, whenever, by the ſea's deſtroying the out-works, it ſhall appear adviſeable and neceſſary; but yet, as the timber and iron-work thereof have already been expoſed for ſeveral years to the weather, it is my opinion that they will laſt as long, when expoſed in the ſame manner, as if put under cover.

Auſthorpe, 30th April, 1776. J. SMEATON.

ESTIMATE for rebuilding the part of the wall of the low light at *Spurn Point,* that was taken away by the ſea, and defending the ſame, as per Report.

	£.	s.	d.
To thirteen rods of brickwork, at 10 *l.*	130	0	0
To timber and piling under the foundations,	35	0	0
To *Hazlecliff* ſtone, inſide the wall and out, 360 tons, at 6 *s.* 8 *d.*	120	0	0
To clearing foundations,	5	0	0
To gryne-work of faſcinery,	10	0	0
Neat eſtimate,	300	0	0
To 10 per cent. contingencies upon the whole,	30	0	0
	£. 330	0	0

ESTIMATE

ESTIMATE for taking down, moving, and re-erecting the great temporary light, and placing the fame in line of the other two light-houfes.

	£.	s.	d.
To taking down, - - - - - - - - -	5	0	0
Removing, - - - - - - - -	5	0	0
Repairs that may be wanted, - - - - - - -	15	0	0
New foundation, fo as to be moveable, - - - - -	25	0	0
Re-erecting the fame, - - - - - - -	10	0	0
Neat eftimate, - - - -	60	0	0
To 10 per cent. contingencies, - -	6	0	0
	£. 66	0	0

Aufthorpe, 30th April, 1776. J. SMEATON.

ESTIMATE of what I have further ordered as neceffary to compleat the light-houfes at *Spurn Point*.

	£.	s.	d.
A copper funnel for the great light-houfe, to be fixed in the fame manner as that of the low light, and of a proportionable fize; this, after deducting the value of the prefent funnel, to be returned, - - - - - - - -	18	0	0
To fixing, fcrews, bolts, &c. - - - - - - -	5	10	0
New caft-iron fire-hearths, poffibly may come to about - - - -	5	0	0
Some partitioning in the fmall light-houfe pipe-room, in order to make it convenient to lodge in; an addition to the afh-pipe; and feveral fmall jobs that I faw neceffary, and ordered when I was there laft, about - - - - - -	6	10	0
	£. 35	0	0

Aufthorpe, 22d January, 1777. J. SMEATON.

 The

The conclufive REPORT of JOHN SMEATON, Engineer, concerning the *Spurn* Light-houfes.

IN confequence of Mr. TAYLOR's letter of the 30th of March laft, acquainting me that every thing I had ordered, as well extra as contract work, was done, I vifited the light-houfes, at *Spurn Point*, upon the 7th of April, and finding that the capping of the detached circular wall of the lower light was compleated, which for fome months paft had been the only thing wanted to the completion of his contract works, I gave him a certificate accordingly, of which I advifed the Board by letter of the 20th of April; and alfo therein mentioned, that having ftaid the night of the 7th upon the *Spurn*, that the large copper funnel then fixed upon the great light-houfe compleatly anfwered the end, as the leffer one fixed upon the low light had done before, fo that both lanthorns would go through the whole night, without any neceffity for cleaning during the night; and that both lights appear exceedingly brilliant, and the heat within the lanthorns is proportionably lefs. Thefe are, in fact, very great and effential improvements, both in regard to the light itfelf, and the advantage of keeping them, and therefore directly tending to keep the expence of maintenance as low as is confiftent with the goodnefs of the light neceffary to be exhibited, and which, as thefe light-houfes differ materially in conftruction from any before erected, are matters that could only be adjufted by trial and experience, but which being once brought to bear, will be a model or example for the erection of others. On examination, I found that the grates I had ordered for the new hearths, being as much too fmall and narrow as the original ones were too large and wide, the light-keeper (being by trade a fmith) had made one for the great light a medium between the two, which had anfwered, not only for the *Stone* coal, but for burning a mixture with the *Sunderland* coals, which, as the Board did not approve the difpofal thereof, was become the more neceffary; but the lefs lights grate being too narrow to burn the *Sunderland* coal, I thought proper to order another grate alfo for the leffer light, by means whereof they faid they could burn one third of *Sunderland* with two thirds of *Stone* coals; and, according to this rate of confumption, they had as many of the *Stone* coals as would laft till Midfummer, (of which I took care to apprize Mr. CORTHINE, the agent,) and as many *Sunderland* coals as would laft feveral years. Indeed the *Sunderland* coals are much in the way, as, by occupying the coal vaults, the *Stone* coals have been obliged to be lodged in the yards, and receive much damage by being expofed to the rains and the frofts.

I obferved that a good deal of gravel and beach had been laid on before the leffer light, and that no material variation had happened in the Point; in fhort, that things appeared

appeared in as tenable ſituation in every reſpect, as they had done twelve months before, when I adviſed the rebuilding the wall; and though, according to the accounts I have ſince received from Mr. TAYLOR, more beach is ſtill laid on, and matters appear ſtill more promiſing, yet, as in the great ſtorm at N. E. that happened in February laſt, the whole of the Hazlecliff rubble was diſperſed from the S. E. ſide of the wall for 60 feet running; and though much pains and care appear to have been taken by Mr. TAYLOR in collecting and replacing the ſame from time to time, yet the total ſtock laid outſide the wall has been upon the whole conſiderably diminiſhed; and as ſtorms of this kind muſt be expected every winter, and there does not appear to me, though a temporary defence, any thing more likely to be effectual, or to afford a better chance of ſaving the building for a term of years, without going into expences that cannot with any propriety be ſupported, as being greater than the expence of the building itſelf; I would therefore by all means recommend that for the preſent year 150 tons of *Hazlecliff* ſtone be got to the place ready to be applied as heretofore, that is, as it may be wanted; and as I have no doubt but that Mr. TAYLOR, while he remains an inhabitant of the *Spurn Point*, will not be wanting in his beſt endeavours to apply theſe ſtones to the beſt advantage for the defence of the buildings, I would adviſe the application thereof to be put under his management until Mr. CORTHINE can fall upon ſome more eligible perſon. Yet I muſt do Mr. TAYLOR the juſtice to ſay, that excluſive of ſuch delay and diſappointment as has ariſen from other perſons, that in his own perſon I think him ſtrictly honeſt and induſtrious; and I apprehend it is very poſſible that after they have got into a way of uſing the ſtones in a leſſer body, and occaſionally as they are wanted, that 100 tons annually may ſuffice, I mean till an extraordinary revolution happens, for in that caſe I don't apprehend that 1000 tons would be effectual.

I have already acquainted the board that the high light machine being erected upon the line, it can in two hours be lighted, ſo that no damage can happen to navigation by any failure of exhibiting proper lights; and as the machine is placed upon ground walls, by continuing theſe walls, and getting the machine upon rollers, it can with great eaſe be drawn further within land, whenever the wearing away of the coaſt ſhall require it.

J. SMEATON.

Auſthorpe, June 23, 1777.

P. S. The running out and ſhaping of the point itſelf was, when I was there laſt, much in the ſame ſtate as it was in the year 1774.

The

The Report of JOHN SMEATON, Engineer, upon the ſtate and condition of the low light-houſe at *Spurn Point*, pointing out the moſt likely means of preſerving the ſame at a moderate expence.

IN the year 1766, I attended a deputation of gentlemen of the Trinity-Houſes of *Deptford Strond* and of *Hull*, who were alſo attended by Capt. MITCHELL, who was ſuppoſed to know the coaſt the beſt of any body: he had peeviouſly ſet up marks for the placing of the light-houſes, according to his own opinion; the line of direction was the ſame in which they now ſtand as to the points of the compaſs, but was more inland, that is, further from the Point than the line upon which the preſent buildings ſtand. It was then obſerved by the gentlemen, that the removal of the preſent light-houſe was on account of its being too far from the Point; and as the Point appeared to be increaſing, and going out further and further yearly, that the new light-houſes might not ſoon become again neceſſary to be removed and rebuilt, it was deſirable to have them as near the Point as poſſible, as the probability was, that they would by the increaſe of the Point leave the houſes more and more within the land. The only difficulty then ſeemed to be, whether the buildings could be ſo founded as to ſtand upright upon this great bed of ſand, if built ſo much nearer the high water mark, upon which I ſaid I could undertake to make foundations upon any part of the bed of ſand, ſo as to enable the buildings to ſtand upright upon their baſes, provided they were out of the way of the immediate ſtroke of the ſea; and as it was univerſally allowed by all preſent that the land was increaſing there in every direction, there could be little danger of a direct attack of the ſea upon either building, and therefore the gentlemen ordered marks to be put down in the line on which they now ſtand, at the diſtance of 300 yards from each other, and which line was then only 115 yards diſtant from the extreme point at high water mark.

It was not till the year 1771 that the buildings were begun to be erected, when on reviſiting the Point I found that it had ſo much increaſed in *length* that it projected at high water mark 280 yards further out than it did in the year 1766. The land had alſo increaſed on the ſide next the *Humber*, but had ſhewn a very apparent diminution to ſeaward. It had been determined to begin with the ſmall light-houſe firſt, which being a leſs ponderous building, if any difficulty ſhould ariſe in making a foundation, it might be a forewarning, and thereby furniſh the means of conquering the difficulties that might attend the larger and more ponderous building.

Under

Under theſe circumſtances of the Point's having lengthened 280 yards in five years, it did not ſeem at all prudent to carry the line of the building further from the Point than had been directed, nor, on account of the diminution to ſeaward, to carry it further out; but finding room on the ſide next the *Humber*, I adviſed that they ſhould be carried 80 yards further towards the *Humber*, upon the ſame line, than originally they had been propoſed, and accordingly the foundation of the ſmaller light-houſe in queſtion was laid 80 yards more inland than originally marked out, being there no leſs than 90 yards within land from high water mark, which ſeemed to be a very ample allowance for the incroachment of the ſea, that hitherto was not ſuppoſed to be any other than caſual, and that therefore in all probability would increaſe again on that ſide as well as the reſt: I alſo on this account ordered the foundation of the building to be furniſhed with a greater number of piles than originally intended. Having never been at the *Spurn* otherwiſe than by water, previous to the laying the foundation of the leſſer light-houſe, it was not till that building was conſiderably advanced that I had an opportunity of remarking the progreſſive effect of the ſea upon the coaſt, which my frequent journies by land during the progreſs of the work gave me an opportunity of ſeeing. In the year 1772 the great light-houſe was founded, and though there appeared no diminution of the land on that ſide, yet by way of precaution I adviſed it to be ſet only 60 yards from its firſt intended poſition towards the *Humber*, inſtead of 80, which kept it 20 yards further from the *Humber* than according to the former poſition, and alſo by way of further ſecurity, I ordered this foundation to have an additional number of piles in like manner as the former. During the carrying on of theſe buildings, I not only remarked that the ſea was making gradual approaches toward the leſſer light-houſe, but was wearing away the ſolid land of the coaſt for many miles to the north of the *Spurn*: however, its progreſs was not ſuch as to denote any immediate deſtruction, till a great ſtorm happening in January, 1776, that in two tides made ſuch an incroachment upon the land as to take away the ground from under a part of the foundation of the circular wall, which occaſioned one half of it to be beat down, and waſhed away the ground ſo as to lay bare a part of the piling upon which the main building ſtood; and had it not been for the precaution of the additional number of piles in its firſt founding, it moſt certainly had given way; however, there did uot happen the leaſt ſhrink.

On this alarming occaſion, I defended the building with all the expedition that could be uſed by a large quantity of *Hazlecliff* rubble ſtone, forming a ſlope againſt the ſide of it to ſeaward, and in the advance of the ſpring the ſea rather retreated than further waſted the ground. Seeing therefore, from the gradual waſting of the whole coaſt, that nothing could be a permanent defence to this building but what would defend it as an iſland, after the ſea had taken the land away round about it, and as this could not be

done

done but at the expence of ſome thouſand pounds, a much greater expence than what would erect a new building, I therefore adviſed, as the cheapeſt defence that could be made, ſo as to give it the beſt chance for a time, to rebuild the circular wall, founding it as deep as we were able at a moderate expence, and ſetting it upon piles, and ſurrounding the wall alſo with a ſlope of *Hazlecliff* ſtone, and, as a dernier reſort, to erect the large temporary light machine in the line of the two buildings, 30 yards from the center of the ſmaller light-houſe more inland, and to repair and fit up the ſame ready for lighting, at two hours warning, ſo that in caſe any ſudden or violent ſtorm ſhould render the houſe unfit for ſervice, recourſe could immediately be had to the machine light to continue the duty, all which was executed in the courſe of the following ſummer.

The beginning of the year 1777 there happened another violent ſtorm at N. E. which the work ſuſtained without any other derangement than that a part of the *Hazlecliff* ſtones laid on the outſide of the wall was diſperſed; therefore, after ſeeing the effects of this ſtorm, I left it as my laſt advice, that " as ſtorms of this kind muſt be expected every winter, there did not appear to me (though a temporary defence) any thing more likely to be effectual, or to afford a better chance of ſaving the building for a term of years, (without going into expences that cannot with any degree of propriety be ſupported, as being greater than the expences of the building itſelf,) than a proper application of *Hazlecliff* ſtones; I therefore recommended that for the preſent year (1777) 150 tons of *Hazlecliff* ſtones be got to the place ready to be applied as heretofore, that is, as it may be wanted, apprehending it is very poſſible that after they have got into the way of uſing the ſtones in a leſs body, and occaſionally as they are wanted, that 100 tons annually might ſuffice, that is, till an extraordinary revolution happens, for in that caſe I don't apprehend that 1000 tons would be effectual."

At the ſame time I obſerved, that the high light machine being erected upon the line, it can in two hours be lighted, ſo that no damage can happen to the navigation by any failure of exhibiting proper lights; and as the machine is placed upon ground walls, by continuing theſe walls and getting the machine upon rollers, it can with great eaſe be drawn further within land, whenever the wearing away of the coaſt ſhall require it.

Auſthorpe, 27th June, 1778. J. SMEATON.

The

The REPORT of JOHN SMEATON, Engineer, concerning the ſituation of the Mills and Bleach Field at *Waltham Abbey* in reſpect of water.

THE bleach field is at preſent ſupplied with water, without diverting any water from the mills, as follows; the ditches are filled by the water from the barge river, which in time of fluſhes riſes high enough to fill them, which fluſhes are conſtantly twice a week in the drieſt ſeaſons; the water for waſhing is the water that continually makes its way down the barge river, and in the drieſt ſeaſons, when the mills keep the water below the top of Sir WILLIAM WAKE's turnpike, the leakage thereof is found ſufficient for the purpoſe, as I am informed.

When the navigation is diverted from its preſent courſe, and this turnpike rebuilt, or ſomething in lieu thereof, to hold up the head of water for the mills, it is apprehended that the turnpike may then be made ſo water-tight, and the leakage thereof ſo ſmall as not to change the water of the preſent barge-river with ſufficient ſpeed, to anſwer the purpoſe of waſhing the linens; nor can the ditches be then ſupplied with water as they now are for want of the fluſhes.

But the ditches may be ſupplied with water by a bore running continually out of the *Waltham Abbey* mill-pond, and the waſhing may be ſupplied by a bore running continually (or in the day-time) from the new-conſtructed turnpike or flood-gate; this will, however, ſo far as it goes, be a ſubtraction from the mill's water, but yet may be done ſo as not to affect the powder-mills at all, and the Abbey mills very inconſiderably; on the other hand, it will be proved that both will be great gainers in point of water by the alteration.

Having, with the aſſiſtance of Mr. YEOMAN, Engineer, carefully viewed, meaſured, and calculated the quantity of water diſcharged at Sir WILLIAM WAKE's turnpike in the drieſt ſeaſons for paſſing the barges, it appears to amount to conſiderably more than 14 * millions of cubic feet of water weekly, which, reduced to an average of the whole week, will amount to $1429\frac{1}{2}$ cubic feet per minute, flowing continually, and which would ſupply a bore or round hole in a plank of $23\frac{1}{2}$ inches diameter, whoſe center is 2 feet below the ſurface of the water in the head from whence it is ſupplied; this is certainly a very great loſs of water to the mills, and which muſt continue ſo long as the navigation remains in its preſent ſtate, the greateſt † part whereof will be ſaved to the mills jointly by the alteration.

* The number comes out 14,408,875 cube feet per week.

† The quantity expended by the new navigation will not be above $\frac{1}{18}$ part of the preſent to do the buſineſs.

Let

Let us now examine what will anſwer the purpoſes of the bleach-field: having computed the quantities of water taken in for the ſupply of the ditches weekly, according to the information of the owner, I find it amounts to 140000 cube feet, that is at the rate of 14 cube feet per minute nearly, which will be ſupplied by a hole of 2 $\frac{3}{4}$ inches diameter, running conſtantly, made in a braſs or copper plate of $\frac{1}{8}$ of an inch thick, and whoſe center is placed 1 foot below the ſurface of *Waltham Abbey* mill-pond.

The ſupply of water for waſhing, ſuppoſing it done in the open river, as at preſent, would be conſiderable; but as the width of the ſtream, when barges ceaſe to paſs that way, may, without detriment to the diſcharge of the flood water, be contracted at low water from 36 to 9 feet before the waſhing-ſtages, it will follow, that $\frac{1}{4}$ of the ſupply will produce the ſame velocity of the water in the river as at preſent, and conſequently $\frac{1}{4}$ part of the leakage may ſupply it; but as the leakage of the new flood-gates may not be an 100th part of that at preſent, and greater or leſs according to the different ſtates of repair they may be in, we will calculate what opening will ſupply, ſuppoſing no leakage at all.

The quantity neceſſary, when contracted as above, appears to be 135 cubic feet per minute, which will be diſcharged by a hole in a braſs or copper plate of 7 $\frac{1}{8}$ inches diameter, the center being placed at 2 feet below the ſurface of a full head.

This quantity, with the former for the ditches, makes 149 cube feet per minute; but the quantity expended at the turnpike by the fluſhes being 1429 $\frac{1}{2}$ per minute, the quantity requiſite for the bleach-field will be only betwixt $\frac{1}{9}$ and $\frac{1}{10}$ part of the water expended at the turnpike for navigation. Hence it appears, that upon the whole, at leaſt eight parts in nine of the preſent water loſt to the mill by the navigation will be ſaved, and yet the bleach-field amply ſerved: hence, though the whole object of loſs is trifling in proportion to the gain, yet there appears a method by which the waters gained may be minutely and juſtly divided; for if an additional bore be allowed the powder-mills, equivalent to the 7 inch bore at the turnpike, each property then will be equally benefited; for as the water of the bore taken from *Waltham Abbey* mill head would otherwiſe be drawn at the mill, there ought to be no equivalent to the powder-mills on that account.

The account therefore will ſtand thus: To avoid fractions, I will ſuppoſe $\frac{1}{9}$ part of the ſavings to go to the bleach-field, which being wholly deducted from *Waltham* mill, a 4 $\frac{1}{2}$ part will go to the powder-mill as its full due, and a 3 $\frac{1}{2}$ part to *Waltham* mill.

The

The *Waltham* miller on this occafion, as ufual, may not think he has his due, becaufe he will not get in the very fame proportion as his neighbour; but let us examine what he will get, and then his right to complain will be better judged of.

When I meafured the mill's draught of water on Wednefday the 13th inftant, I found the mill expending at the rate of 1087 cube feet of water per minute, and, as the miller faid, was capable with that water of grinding and finifhing about 4 bufhels of wheat per hour; and he further faid, that in fhort water times he frequently had not the average of that water to go conftant for the whole 24 hours; the quantity faved will therefore be as follows:

	Ft.
The average of water expended by the navigation per minute being $1429\frac{1}{2}$ cube feet, and the half of this being fuppofed due to Sir WILLIAM WAKE, will be - - - - - - - -	$714\frac{3}{4}$
From this deduct the whole water for the bleach-field, - -	149
Saved to the miller by the alteration, befides fupplying the bleach-field,	$565\frac{3}{4}$

Which appears to be more than $\frac{1}{2}$ of the water that he is in dry feafons poffeffed of, and fufficient to make an addition to his grinding of 2 bufhels an hour conftantly; fo that inftead of being injured, he will be greatly benefited.

But as fome water will always leak at the turnpike, and as it is probable fprings arife in the channel of the river, I apprehend a bore of 6 inches, at 2 feet under the top of the turnpike, will be a fufficient fupply for the wafhing, and the equivalent will be moft properly adjufted either by applying a new opening, or by widening the prefent one at the loweft orifice belonging to the powder mills. The fize or widening of the prefent opening, if that method of adjuftment is approved of, I fhall be ready to compute.

London, May 16, 1767. J. SMEATON.

N. B. The computation of 135 cube feet for the bleach-field wafhing, is computed upon a fuppofition of the waters moving 10 feet per minute in a channel of 9 feet wide, and at an average of 18 inches deep.

REPORT on *Waltham Abbey* Powder Mills, refpecting navigation on the river *Lea*.

WE, whofe names are underwritten, having, the 27th of February, 1771, infpected the powder-mills of *Waltham Abbey*, belonging to BOUCHIER WALTON, Efq; as alfo the feveral works of navigation from *Rammy Mead* lock to *King's Weir*, upon the river *Lea*, in order to examine how far the faid mills are, or may be, affected by the faid navigation works, are of opinion as follows.

1ft. That the faid mills are confiderably affected in their going when the water is held up by the new ftop, called *Waltham* ftop, fo as to make more than 3 feet, which is efteemed navigable water, upon the threfhold of the lower gates of *Waltham* lock.

2d. That the faid mills are affected, though in a lefs degree, even when there is 3 feet, and not more, of water over the lower gate threfhold of *Waltham* lock.

3d. We alfo obferve, that the faid mills are affected by the water-courfe leading from the faid mills to the river, being not fufficiently clear of gravel, weeds, &c.

4th. It appears that the faid mills become alfo affected by the paffages for the water at Mr. WALTON's weir, called the corning-engine weir, not being fufficiently ample, in confequence of the circumftance above mentioned.

Upon the foregoing matters we propofe and recommend as follows.

1ft. That a ftone fhould be firmly put down in a confpicuous place near *Waltham* ftop, to mark the height of 3 feet water upon the threfhold of the lower gates of *Waltham* lock, and that the keeper of the ftop fhould have ftrict orders from the Commiffioners of the navigation at all times to draw the gates of that ftop, fo far as to prevent the water rifing there at any times above the faid mark, unlefs requefted for the fake of navigation to the faid mills, or the town of *Waltham Abbey*, and unlefs in time of floods, when all the gates being drawn will not prevent it.

2d. After Mr. WALTON has cleared the obftructions in the water-courfes leading from his mills to the river, that what obftruction to the going of the mill ftill remains, be relieved by enlarging the water-way at the corning-engine weir, which we are of opinion will be done by an additional conduit or paffage of 10 feet wide, its floor to be

be laid as low as the floor of the ſaid weir, and to be furniſhed with a draw-gate or pointing doors to pen the water occaſionally, ſo as to enable the barges to paſs to the mills as at preſent; and as this enlargement can only become neceſſary by the water being pent at *Waltham* ſtop too high for the powder-mills, even at 3 feet above the lower gate ſill of the ſaid *Waltham* lock, we are of opinion that this alteration ſhould be made at the expence of the navigation.

Having alſo inſpected JONES's turnpike, we found it not only out of repair, but materially defective, as the gate could not be ſhut down within ſome inches, and thereby a great quantity of water ſuffered to go down the old barge river, to the detriment of the mills aforeſaid, as well as others dependant on the ſaid head of water. Reſpecting which we are of opinion, that the ſaid turnpike ſhould be kept in good repair, on account of the ſaid mills, and that the particular defect of not ſhutting down ſhould be remedied as ſoon as poſſible.

We are informed, and believe it to be true, that the bargemen going downwards, after having paſſed the aqueduct lock next *King's Weir*, and taken the quantity of water neceſſary for paſſing them through the ſame, frequently draw a further quantity to keep them forward, by which means an unneceſſary quantity of water is brought down the canal, whereby the ſaid mills are not only detrimented by the loſs of water, but the navigation itſelf; for beſides impairing the banks of the canal, the current that helps barges going down obſtructs thoſe going up: it ſeems therefore neceſſary that proper orders ſhould be given to the perſon having the care of the new ſtop of *King's Weir*, or otherwiſe to prevent theſe abuſes.

London, March 27, 1771. J. SMEATON.

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The REPORT of JOHN SMEATON, Engineer, upon the ſtate of the river *Lea* navigation, ſo far as the mills abreaſt of *Waltham Abbey* canal are affected thereby.

APRIL 3, 1779, at the deſire of BOUCHIER WALTON, Eſq; owner of the powder-mills at *Waltham Abbey*, I viewed the ſtate and condition of the river *Lea* navigation, from and incluſive of the lock upon the cut next below *Waltham Abbey* cut or canal, up by the courſe of the ſaid canal to *King's Weir*, and found the ſame as follows.

All the locks conſtructed without walled chambers, by which means not only much more water is neceſſarily expended at each lock for the paſſage of every veſſel, but the paſſage of the veſſels themſelves are proportionably retarded by taking more time to fill and empty.

The head gates of all the locks within the above diſtrict were ſo conſiderably leaky, againſt which the water ought conſtantly to lay, except during the time of veſſels paſſing, that I could not eſtimate the conſtant leakage at leſs than one of Mr. WALTON's mill ſtreams, which in conſequence in all dry ſeaſons is loſt amongſt the three ſets of mills abreaſt of this cut, viz. *Enfield* mills, *Waltham Abbey* powder-mills, and *Waltham Abbey* corn-mills, and which waſte of water alſo retards the paſſage of the veſſels, and which retardation, as well as waſte of water, is alſo increaſed in caſe the tail gates are out of order, as I have reaſon to ſuppoſe they are, the tail gates of the lock near the head of the cut next below *Waltham Abbey* cut, which was the only lock through which I ſaw any veſſels paſs were very much ſo.

The waſtes of water above ſpecified, though very material to the mills, are yet very trifling in proportion to the waſte that will be occaſioned, in caſe what I was informed of be really the practice, as I have reaſon to believe it is, viz. that veſſels going down very frequently, if not always, after the lock is emptied, and the veſſel is let down to the level of the lower canal, draw the cloughs or ſlakers of the head gates, and leave them both running a full bore of water, the ſame as while the lock is filling, in order to make a current down the cut to eaſe the horſes, and help them forward upon their paſſage; and leave them running without returning to ſhut them, ſo that in fact they run till ſome other perſon has occaſion to ſhut them, and during this time, which is indeterminate, a conſiderable portion of the whole river when water is ſcarce will paſs this way, and be loſt to the mills abovementioned; it being a rule that what is loſt at one lock, will alſo be loſt to all the reſt upon the ſame canal, or head of water. This is a practice that ought by no means to be ſuffered, as beſides a damage of indeterminate magnitude to the mills,

it

it is a very great and manifest detriment and hindrance to the navigation itself; because whatever small benefit it may be to the ease of passage of vessels going down, it will be a greater hindrance to vessels going up; and when it happens, as must frequently be the case, that when any of the reaches of the canal or heads of water are drawn down from above, the vessels going up will be prevented navigating through the same, and must wait till those reaches are filled, by letting the water down from above in the canals, or till supplied by the currency of the river *Lea* in the open river; which hindrances to the navigation itself very greatly surpasses any advantage that can be drawn from the flashing of the vessels downwards.

These evils therefore are worthy of remedy merely for the facility of the navigation itself, but as relating to the mills, which can only have the surplusage, will be very destructive in dry seasons; and, I believe I may take upon me to say, very contrary to the idea wherewith the improvements were first framed before the last Act of Parliament was applied for.

For remedy whereof, as far as regards the first, viz. the wharfing up of the lock chambers, it is very difficult to be done now in a substantial manner with brick, as it will occasion the stoppage of the navigation for the time; but they may be wharfed up with piles, planks, and land ties, keeping the navigation open; and where any of the locks so far fail as to need the water to be taken off, they may be wharfed with brick, as, to be substantial, they should have been done at first.

2d. As the mills are more immediately hurt by the leakages of the lock gates, than the navigation, the mill owners and lessees should have power to repair the leakage of the gates, and charge those repairs to the trustees of the navigation, in case they do not do it on competent notice given by the respective millers.

3d. The practice of flashing I do not see any adequate remedy to prevent, but by having a man or lock-keeper to attend each lock, by which the mills can be affected, with a proper hut to skreen him from the weather; and two men will be necessary in case the navigation is unrestrained to all hours of the night; which men, as they become necessary by the misapplication of the bargemen of the proper mode and utensils of navigation, and being also for the benefit of the navigation, should, as it seems to me, be paid by the navigation, or a tax laid upon the bargemen; but being for the security of the millers, should be chosen or dismissed by the mill owners or lessees immediately interested. Those men (it being made their duty so to do) will prevent much wear and tear in the use of the locks, and by attending to keep the respective heads of water constantly

ſtantly full, with as little waſte as poſſible, will thereby ſave much more time to the bargemen in the courſe of a voyage up and down, than they can poſſibly gain by any miſapplication of the water.

I muſt alſo obſerve that the banks in many places are too low and too weak, ſo that when the water goes over them it cuts them down in gullies, and this will neceſſarily, during the continuance thereof, occaſion an extraordinary waſte of water through the whole of ſuch canals.

I alſo viewed the old turnpike, called Sir WILLIAM WAKE's turnpike, which, before the navigation was altered, was uſed as a pen of water, by means whereof, and through which the navigation paſſed, but now is of no other uſe but to open in time of floods, and to be kept ſhut at all other times, to pen up water for the ſervice of *Waltham Abbey* powder-mills, and corn-mill, as heretofore, and which for that reaſon ſhould be kept free from unneceſſary leakage. When I ſaw it, by temporary repairs, it was ſufficiently tight; but as it appeared to me, its main timbers and general ſtate of repair and ſtrength, was ſo much impaired that I ſhould not be ſurpriſed if the firſt great flood of the *Lea* ſhould take it away, in which caſe both the ſets of mills at *Waltham Abbey* would be deprived of their water; it therefore ſeems, that though it is by law to be repaired at the navigation's expence, yet being no longer neceſſary thereto, it would be proper for the owners of theſe mills to take the rebuilding and future repairs upon themſelves upon a moderate allowance from the navigation.

J. SMEATON.

Auſthorpe, April 17, 1779.

To

To the Truſtees of the River *Lea.*

The REPORT of JOHN SMEATON, Engineer, reſpecting the alterations made at *Sewardſton* mill, ſo far as they concern the quantity of water taken from the river *Lea,* as alſo the loſs ſuſtained by *Sewardſton* mill by an alteration made at *Enfield* lock in the year 1781.

HAVING received no commiſſion from the Truſtees of the river *Lea* to determine any thing betwixt parties, I take the opportunity of reporting my opinion, as a profeſſional man, upon the premiſes.

On Saturday the 26th of October laſt I carefully viewed and examined the mill of *Sewardſton,* as alſo the preſent ſtate and condition of the gage ſluice called *Enfield* lock, by which water is taken to *Enfield* mill.

Reſpecting *Sewardſton* mill, and hearing what is alledged and agreed on both ſides, in point of fact, is, that it has undergone no alteration except that of laying the floor of the corn-mill conduit lower, and the conſtruction of the water-wheel correſpondent thereto; that the ſell or threſhold over which the water iſſues, as well as the width of the gate, remains the ſame; this alteration, therefore, I am of opinion, will have the effect of grinding more corn with the ſame quantity of water, but not of requiring more water to grind the ſame quantity of corn, and to the height to which a miller may lift his gate or ſhuttle, I can conceive he can be under no reſtriction.

The mill being tried in my preſence, with a full head of water, it appeared to diſpatch at the rate of upwards of 100 quarters of wheat per week.

I alſo took an admeaſurement of the quantity of water uſed while working at the rate abovementioned.

I examined the preſent ſtate of *Enfield* lock, being now reſtored to its former ſtate before the alteration, and to the ſatisfaction of Mr. WHISLER; and comparing this with a model produced by Mr. WHISLER, and afterwards authenticated by Mr. NICHOLLS, as carefully made by him from meaſures taken at the time when the water was diverted into *Enfield* cut, in favour of the navigation in a greater proportion than formerly; I ſay, comparing this model with the ſtate of the lock as I found it, it appears to me, that there would go into *Enfield* cut or mill river at that time conſiderably more water (over and above

above what ought to have gone through the proper gage) than was taken by *Sewardston* mill to grind above 100 quarters per week, as above specified.

But as at the time of the complaint the waters ran so short that it was impossible to have kept up his mill-head to the height I saw it, and therefore could not have ground the same quantity of corn with the same quantity of water, Mr. WHISLER lays his account in his ability of only dispatching 50 quarters per week had the water been undisturbed; but reduced in the manner it appears to have been, he actually dispatched but 20 quarters per week, thereby losing *bonâ fide* 30 quarters per week of what he might, and would have done, agreeable to what he has stated in his case of the 14th of February last, addressed to the Trustees of the river *Lea*.

As therefore it does not appear to me that Mr. WHISLER has made any alteration that enables him to take more water than he is entitled to; and as there does not appear any thing that shall checque, so as to reduce the quantity of grinding lost per week, but rather that from the above circumstances Mr. WHISLER's statement of 30 quarters per week appears probable and well founded, I therefore see nothing that ought to hinder the admission of that quantity lost per week.

The whole length of time stated in Mr. WHISLER's case of 12 weeks and 5 days I don't find controverted, which he reduces a fortnight on account of the time the gages were shut down for cleansing the navigation; but as during this time he would have the whole water of the river *Lea*, he would be enabled to maintain a full head, notwithstanding the driness of the season; and therefore in that fortnight could dispatch above 200 quarters, that is, above 100 quarters more than the ordinary rate for a dry season if the water had been divided betwixt *Enfield* mill and himself, as usual. This 100 quarters will therefore compensate the loss of 30 quarters per week for three weeks and two days, which, applied as a further set off, will reduce the whole time that the loss of grinding continued, to seven weeks and three days.

Respecting the rate at which he charges the loss of grinding, viz. 9*l.* per week upon 30 quarters, that is, at the rate of 6*s.* per quarter, or of 30*s.* per load, a price that I apprehend to be very far beyond the ordinary accustomed price of grinding in that district of country.

This is not to be doubted, that about the time of the hindrance mentioned, there never was known in man's memory so great and long-continued a drought, and therefore all mills being short of water, there would be a great want of meal at the *London* market, and

and thofe who ground their own corn (as it is alledged Mr. WHISLER does) and could get it to market, would doubtlefs get extraordinary profits; but as on this head no evidence was laid before me, and it being a mere matter of traffic no ways determinable by rules of engineery, I muft of neceffity refer this point entirely to the Truftees, to fatisfy themfelves by fuch evidence of the fact at the time, as fhall further occur, or be laid before them.

It has been obferved to me, that the mouth of the mill-ftream of *Sewardfton* mill has been widened, contrary to a claufe in the Act of Parliament, which allows that every part may be made wide enough for navigation to *Sewardfton* mill, which widening, on the other hand, has been denied *as to the mouth*; I can therefore only fay, it is of little confequence to the navigation of the river if wide enough at the mouth for a barge, and there is no reftraint as to the depth. This reftriction as to the mouth feems to have been introduced as a fecurity to *Enfield* mill, that drawing from one common pond above *Enfield* lock, *Sewardfton* mill fhould not get more than its fhare.

Aufthorpe, November 12, 1782. J. SMEATON.

To the Truſtees of the river *Lea.*

The REPORT of JOHN SMEATON, Engineer, reſpecting the loſs of grinding ſuſtained at *Tottenham* mills by the leakage of the lock gates, from the year 1778, till April, 1781.

HAVING received no commiſſion from the Truſtees of the river *Lea* to determine any thing betwixt parties, I take the opportunity of reporting my opinion, as a profeſſional man, upon the ſubject before me.

Being favoured by Mr. WYBURD with the ſtate of his demand upon the Truſtees of the river *Lea*, I find it conſiſting of various articles; but ſo far as my judgment may be ſuppoſed to be of uſe upon the ſame, it muſt be in thoſe articles containing a charge for loſs of grinding at thoſe mills during a term, from the year 1778, to the 2d of April, 1781, occaſioned by a needleſs loſs of water, ariſing from the diſrepair of *Tottenham* lock during that time.

In this account Mr. WYBURD particularly ſtates the loſs from the 30th of October, 1780, to the 2d of April, 1781, according to notice given to the Truſtees of the loſs he then ſuppoſed himſelf to be ſuſtaining, viz. at the rate of 5*l.* 10*s.* per week.

The whole time intervening being 22 weeks, from this he deducts 7 weeks that he was fully ſupplied with water, there then remains 15 weeks, wherein water was loſt in that period, which, charged as above, amounts to 82*l.* 10*s.*

No evidence was adduced to invalidate Mr. WYBURD's charge reſpecting the length of time as above; and it was very ſatisfactorily proved, that not only during that particular period, but for two years before, the lock-gates and ſlakers had been exceedingly leaky, and out of repair, and alſo had been miſuſed, and great quantities of water expended to flaſh boats over a ſhoal, that had remained in the tail of the cut ever ſince its firſt being opened, till deepened 20 inches by Mr. GLYNN, in April, 1781.

Mr. WYBURD being deſired to exhibit ſome teſtimony, whereby it might appear that his charge of 5*l.* 10*s.* per week was properly founded, Mr. BASS, his preſent mill-wright and foreman, alledged, that it was the general opinion of himſelf and millers,

that

that the leakage of the lock-gates was as much as would drive one pair of ſtones. In further teſtimony Mr. WYBURD produced a paper, ſaid to be extracted from his books, at the deſire of one of the Commiſſioners, by which, comparing what the mills had done for 12 weeks after the 20th of June, 1780, with what they did in the ſame period ſucceeding the 20th of June, 1781, after the lock had been repaired, he finds they did more by $30\frac{1}{2}$ quarters per week in the latter year than the former, though it muſt be acknowledged the year 1781 was a dryer year than the year 1780.

He ſtates, that in 12 ſummer weeks, 1780, they ground 1029 quarters					
average, per week,	-		-	-	$85\frac{3}{4}$
Ditto,	-	-	1781,	1395	- $116\frac{1}{4}$
			Difference loſt is	Q^rs	$30\frac{1}{2}$

Upon which (as a fact) Mr. WYBURD reaſons thus: if, when we ground 85 quarters per week we loſt 30, in grinding double that quantity they muſt have a double loſs, and in a triple quantity a triple loſs, and ſo on till they came to five times as much; ſo that when their grinding amounts to 5 times 85, or 425 quarters per week, their loſs amounts to 5 times 30, or 150 quarters.

The different grindings being therefore averaged thus:

1	85	loſt	30
2	170		60
3	255		90
4	340		120
5 times	425		150

divide by 5) 450 (90 quarters per week will therefore be the average loſs, amounting to 18 loads, which, at 7*s.* 3*d.* per load, amounts to 6*l.* 10*s.* 6*d.* per week.

Now Mr. WYBURD, in reaſoning upon the fact above ſtated, takes it for granted, that becauſe a greater head of water which enables them to grind *more* corn, produces alſo *more* leakage, he ſuppoſes them proportionable, ſo that when they can grind five times as much corn, there is five times the leakage; but this is a very evident miſtake, for if with a 6 feet head, and ſuitable follow of water, they grind 425 quarters, the leakage through the ſame apertures, will only increaſe beyond what it would be at the ordinary ſummers head of 4 feet 4 inches by $\frac{1}{5}$ part of the whole, ſo that if, upon grinding 85 quarters, they loſe 30, upon 425 they will only loſe 36, and the average loſs will not exceed 33 quarters per week, that is, 6 loads 3 quarters.

Mr. Wyburd's mode of reafoning upon the fubject, he feems himfelf apprehenfive, if purfued to its extremity, was leading him into an incongruity, for, fays he, "when we grind 500 quarters per week, we don't mind the lofs of water fo much," that is, though when grinding 425 they were reckoning themfelves to lofe, and ought to be paid for 150 quarters, amounting, at the above rate, to 10*l.* 17*s.* 6*d.* per week; yet, when they could do 75 quarters more, and, according to the fame fcale, would lofe the grinding of $26\frac{1}{2}$ quarters in addition, their lofs would not then be worth minding.

That the lofs of 33 quarters per week cannot be far from the truth, will appear by examining fuch collateral circumftances as have occurred.

According to the teftimony of Meffrs. Berner and Rogers, and alfo of James French, who affifted them in examining the gates in queftion, by defire of the Truftees, (which they did the 24th of March, 1781) the whole value of the feveral openings, according to their eftimation, and the water difcharged thereby, compared with the quantity requifite to grind a given quantity of corn, (as deduced from an experiment made by myfelf upon this mill) could not amount to more than one quarter per day; but as the gates were doubtlefs then as carefully fhut-to as the circumftances of their difrepair would admit of, which could not in general be the cafe when handled by bargemen, nor would they, from the fame circumftances of difrepair, always fhut alike, I look upon this experiment as made in their extream degree of tightnefs.

Again, it has been fully afcertained and agreed, that during this ftate of difrepair of the gates, that the lock would fometimes be 15 minutes in filling, and that it was frequently neceffary to draw the head-gates open by the tracking horfe, fometimes being done by fimply drawing them open, and fometimes by the ufe of a block; and that at fuch times, according to the opinion of William Bannister, who preceded William Bass as foreman at thefe mills, the water of the lock has not levelled by about 4 inches: he fpeaks of this, however, by eftimation of the eye, not having ever actually meafured it.

The tail-gates are alfo agreed to have been more leaky than the head-gates; had the tail-gates therefore been no more leaky than the head-gates, we may well fuppofe that 3 inches difference would have been fufficient to have brought as much water through the open flakers of the upper gates, as would have fupplied their own leakage.

Now the quantity of water that would be vended by the two upper flakers upon a difference of 3 inches want of level, will be a given quantity, and will be equivalent

to

to the leakage of the upper gates at these times, and this checked with the quantity of water used for grinding a given quantity of corn, as before-mentioned, will amount to the grinding of $9\frac{1}{2}$ quarters per day: but as it was not necessary for the gates to have been always drawn open in this way, this appears to me to have been the extreme loss the other way, it is therefore fair to check the result obtained this way with what arises from the experiment of Mess. BERNER and ROGERS, viz.

	Qrs. per day.
When the gates were so leaky as not to level within 3 inches, loss	$9\frac{1}{2}$
tight as per Mess. BERNER and ROGERS, to lose but	1
Sum	$10\frac{1}{2}$
Half will be the mean	$5\frac{1}{4}$

So that the average loss thus obtained will be $5\frac{1}{4}$ quarters per day, or $36\frac{3}{4}$ per week, which call 37.

And again, if we check the average result obtained from Mr. WYBURD's experiment, viz. - - - - . 33 quarters per week,
Against the average result last collected - - 37

Sum 70

Average of the averages 35, that is 7 loads,
which at Mr. WYBURD's prices, stated at 7*s.* 3*d.* per load, is 2*l.* 10*s.* 9*d.* per week, and which, in my estimation, will be so near the matter as not materially to injure either party.

£.2 10*s.* 9*d.* per week, then, for 15 weeks is £.38 1*s.* 3*d.*

The idea of the millers, that they were losing as much water at the lock as would work a pair of stones, I must in this place observe I can have no reliance upon; had it passed through an orifice in one collected opening they might have had some comparative notion, but when cascaded in many different directions through the crevices of lock-gates the best judge of these matters would be liable to be greatly deceived, and from the magnitude of the appearance, judge it much more than it really was, and in this manner their idea of loss would be magnified from first to last.

Respecting, therefore, the charge of £.200 for two years preceding the 30th of October, 1780, no particular evidence was offered upon it, but the general one, that during all this period the lock-gates and flakers were greatly out of order; yet, since it appears that at three different times they were repaired, it is impossible to judge now what degree of

of loſs Mr. WYBURD might ſuffer during that period; but if his own comparative idea of the matter be taken, viz. that while he was ſuffering 5*l.* 10*s.* per week in the period ſpecified between the 30th of October, 1780, to the 2d of April, 1781, he was ſuffering at the rate of 100*l.* per annum for the two preceding years, then the yearly allowance muſt be reduced in the ſame proportion as the weekly.

	£.	s.	d.
That is as 5*l.* 10*s.* is to 2*l.* 10*s.* 9*d.* ſo is 200*l.* to	92	5	5
Which, together with what was before aſcertained,	38	1	3
Total for loſs of water	130	6	8

With which I am convinced Mr. WYBURD will be fully recompenſed for whatever loſs he has in reality ſuſtained.

I will only add that I would have it underſtood, that I have ſupported Mr. WYBURD's claim of reparation of injury to an individual as much as I can with juſtice to the Truſtees as a public body; at the ſame time adverting, that as in the nature of the uſe thereof lock-gates cannot be made or kept perfectly tight for any length of time together, that a reaſonable degree of leakage can be claimed by the Truſtees as their right, by the ſame rule as they can take water for the lockage of the veſſels, the mill eſtates upon this river being greatly benefited by the alteration of the mode of navigation from that of wears and flaſhes to that of ciſtern-locks.

J. SMEATON.

Auſthorpe, November 12, 1782.

ST. IVE's

St. IVE's HARBOUR.

The REPORT of John Smeaton, Engineer, concerning the practicability of making the harbour of *St. Ive's* safe for ships in all winds.

THE bay of *St. Ive's* lays about five leagues to the north east of *Cape Cornwall*, and is the first harbour of any consequence after the entry of the north channel; it lays nearly opposite to *Mount's Bay*, upon the entry of the *British* channel; and as there is a great scarcity of harbours on the north side of *Cornwall*, it becomes of consequence from its situation, not only to ships trading through the north channel, but to such ships as homeward bound from long voyages, by hazy weather, or other accidents which often happen, get into the north channel, when they intended to make the south.

For these purposes the bay of *St. Ive's* is happily situated, and is sufficiently capacious, it being near four miles in width and above two miles in depth, having in general, and especially near the middle, full 10 fathoms at low water, with a clean bottom, being altogether a white sand, composed almost wholly of the small fragments of sea shells, so that having very little of what is gritty in its composition, and the particles being rounded by the motion of the sea, is so soft and smooth as not to hurt the cables of such vessels as anchor therein; and as underneath the sand there appears to be a blue clay (it being frequently brought up upon the flukes of the anchors) is very good holding ground, the anchors being never known to drag when drawing towards the land, as the ground that way gently rises, and in the contrary direction, as the wind blows from the landward, the sea will necessarily be smooth, or if driven out to sea can be of no ill consequence, as the passage is sufficiently open, with sea room enough.

At the north-west corner of the bay a bold rocky promontory, called the *Island*, is joined by a narrow neck to the main land, and projecting considerably forwards towards the east, forms a natural harbour on the north-west side of the bay, and defended from all winds except the north-easterly.

This interior bay forms the harbour of *St. Ive's*, and is for the most part left dry at low spring tides; but on account of the fine soft sand before mentioned, that universally lines the bottom of the whole bay, affords a soft easy bed for ships to lay upon when left dry by the tides; and for such ships as have not occasion, cannot, or chuse not to come upon ground, here is an excellent road where ships of any burthen may ride, safe from

from all north-wefterly, wefterly, fouth-wefterly, foutherly, and fouth-eafterly winds, in fix and feven fathoms water, at low water fpring tides, as appears by infpection of the draught of the harbour accompanying this report, where at fig. 6. veffels may ride in fix fathoms, the point of the ifland called the lamp rock being open with the *Meran* point, and bearing N. by the compafs, (as all the bearings herein after mentioned were taken) the *Meran* point diftant fcarce a quarter of a mile. At 7 there is in like manner feven fathoms, the lamp rock bearing N. by W. and at fig. 9. nine fathoms, the lamp rock bearing N. N. W. $\frac{1}{2}$ W. from all which places the church tower bears nearly the fame, viz. W. $\frac{1}{2}$ N. and at the ifland of *Codrevy* E. by N. diftant about $3\frac{1}{2}$ miles; but veffels are by no means confined to thefe places, the water growing regularly and uniformly deeper towards the middle, where the general depth is ten fathoms, but thefe are the marks which fhips bring up by, who ufe the road, in order to be as much fheltered as poffible.

From the fketch of the bay it appears, that the rocks mentioned to be without *Codrevy* ifland, together with *St. Agnes* and *Trevonfe Point*, ftretch north as far as N. E. by E. fo that it appears that the road does not lie quite open except from the north to N. E. by E. thefe winds are not however dangerous on this coaft, as they blow almoft right out of the channel; yet it is defirable, for the fake of fuch veffels as come in here for fhelter from the N. W. and wefterly winds, or to prevent being driven back to *Milford Haven* * when outward bound, or towards the *Scilly Iflands* when homeward bound, and catched with contrary winds; I fay for whatever caufe it may have been advifeable or neceffary to come into this road, it is certainly very defirable that they fhould have a place of refuge in cafe they are catched with a hard gale of wind from N. E. while riding there; for to avoid this poffibility, many fhips are prevented from making ufe of the fhelter the place naturally affords, and by that means meet with an unhappy fate, that might have been very fafe in the road at *St. Ive's*, of which there are many examples.

Conformable to this idea, the ifland beforementioned ftretches away finely to the eaftward, and the caftle point aims very naturally towards the fouth, but does not ftretch away far enough to the fouth to make a fufficient cover for fhips laying aground within the fame from the fwell that is brought round the points when the wind is at N. E. or N. E. by N. for this purpofe it feems requifite that the caftle point fhould be lengthened by art, which, if done in a proper degree, will afford a fhelter for above 60 fail of fhips from all winds; and to this defign occurs the following natural and confiderable advantages.

* *Milford Haven* is 32 leagues to N. N. E. and though an excellent natural harbour when in it, yet its entrance is faid to be with difficulty diftinguifhed in hazy and dark weather.

1ft. There

1ſt. There is a great flow of tide, the ſpring tides in general riſe and fall from 20 to 24 feet; extraordinary great ſpring flow 26 feet from low water, the ſmalleſt at leaſt 18, which leaſt flow, leaving at leaſt 3 feet of water upon the ſand at low water at and within the greateſt part of the ſpace included between the caſtle and *Penolver Points*, it follows that there will be never leſs than 21 feet water at ſpring tides. A neap tide riſes from 14 to 16 feet, and never leſs than 11, but as there will be at leaſt 7 feet water left upon the ſand at low water, it in like manner follows there will ſeldom be leſs than 20 feet water at high water round the pier head, and never leſs than 18.

2d. It is obſerved that on the weſt ſide of the bay, where the road of *St. Ive's* is ſituated, that for three hours flood from low water, the water runs into the bay in a direction N. by E. and after that, though the water continues riſing three hours more, yet the ſet of the current changes to the contrary direction, ſo that the current ſets out of the bay on this ſide nine hours, and into it only three; from hence ariſes this advantage, that if a veſſel is too hard preſſed in the road with wind at any point from N. to E. N. E. ſhe can ſlip her cable, and ſail within the pier whenever there is water, as well before as at or after high water; this ſet of the tide naturally tending to carry her thither, as alſo if outward bound ſhe can go out at half flood, and ſave half her tide up channel.

In ſhort, every circumſtance ſeems to invite the compleating this harbour for the ſafety of ſhips where nature has been ſo bountiful, nor do I ſee but one untoward circumſtance to hinder its perfection, or annoy the ſame; and that ariſes from the great quantity of ſand, of the ſpecies before mentioned, that is brought by the ſea into *that* bay, which is formed by the iſland on the north ſide of the town: this ſand being thrown up by ſpring tides becoming dry, and being of a light nature, is blown by the wind over the neck that joins the *Peninſula* to the main land into the harbour, and comes in ſuch quantities as ſometimes almoſt to bury the houſes that ſtand on that part of the neck. There is no appearance however that this ſand increaſes in the harbour, or ſtays there beyond a certain degree, which is ſomewhat variable according to the winds and tides; from hence it is waſhed into the bay, and from thence part will be carried out to ſea again by the reflux of the tides, and part in time croſſing the bay by circulation, it is blown and heaped up in immenſe quantities on the S. E. ſide of the bay, and in and about the mouth of the *Hale* river at the bottom of the bay, which is now barred till about half tide, and would entirely be choaked up thereby if not kept open by the great land floods. So that upon the whole there is no appearance of the harbour or road being any otherwiſe than they now are in many ages, ſuppoſing all the ſolids to continue as they now are; but it may be reaſonably expected, on the erection of a pier from the caſtle point, that a part of the ſand that is blown over the neck into the harbour, and from thence

now washed away again, may be intercepted by a pier, and there retained; and undoubtedly this in some degree must happen, yet with the precautions that I shall mention, and the provisions that I shall recommend, I am of opinion that the benefit to be expected from a pier ought not to be suspended on account of the inconvenience that may be apprehended from the sands.

In the first place, I would not recommend to carry out the pier further than is necessary to shelter such a number of ships as may probably require to lay in this harbour together; this I apprehend will be done with the length I propose, which is 60 fathoms.

2d. Had it not been on account of the sands, I should not only have proposed to carry the pier out further, but to have turned it more inward like the old pier; but this would in a greater degree have prevented the sands from washing out, nor can it be turned more outwards without laying the harbour too open, and exposing the pier to the direct shock of the seas.

It is probable that, notwithstanding these precautions, the sands will be lodged higher on the inside of the pier than on the outside, as may be seen in the old pier, but yet like those, these will never increase beyond a certain degree, and as there will scarcely ever be less than 20 feet at high water at the pier head, some increase may be admitted without losing the expected benefit: this is exemplified at *Scarborough*, where a considerable quantity of sand is lodged within the pier, yet the utility of the pier, which has been the work of many years, and many thousand pounds, cannot be denied.

To diminish the quantity of sand that now comes over the neck, in case it is found to annoy the harbour, I would propose to build a wall 25 or 30 feet high, supported by proper buttresses, in the direction A B C, by which means the current of sand will be directed so as to go over the low part of the island north of the battery on the *Castle Point*, and be carried into the sea at the little cove between the *Castle Point* and the battery upon *Meran Point*, and thereby *totally avoid* the harbour.

I would also recommend the planting of the sea rushes which are found to entangle the sand, and thereby in great measure prevent its blowing, so that it would be retained in the north bay, where it arises, and increase the breadth of the neck of land that joins the island to the main land.

These things being duly attended to, I am of opinion that the harbour may be kept in a great measure, if not altogether, clear of sand, and if any remains it, may be driven

out

out to ſea by conſtructing a reſervoir to take in the tide water, in order to make a ſcower at low water.

With reſpect to the conſtruction of the pier, that will in a great meaſure depend upon the ground whereon it is to be founded; the immediate bottom where the pier is propoſed, is entirely ſand, ſuch as has been already deſcribed, and is to an unknown depth: I endeavoured to perforate the ſame by a proper inſtrument, but there being 3 feet water over the ſand at low water, though ſpring tide when I was there, it was impracticable to make ſo ſatisfactory a trial as might have been done had the ſand been left dry. However, this far appears, that at a little depth under the ſurface, it lays ſo cloſe and compact that it was with difficulty that a ſharp inſtrument could be got down 3 feet into the ſame. It is ſuppoſed that at ſome depth underneath there is a rock or clay, and it is probable that the rocks which compoſe the *Caſtle Point* may reach under the ſand to a greater extent than they appear above the ſurface, but it ſeems very uncertain whether any rock can be met with whereon to found the pier, the whole, or any conſiderable part of the length. I therefore in the following eſtimate ſuppoſe that there cannot; and therefore propoſe to build the pier without any piles or wood-work, upon the principle which the French call *Pierre perdue,* or caſt ſtones; that is to ſay, to drop a large quantity of rough ſtones in a proper direction and width, ſo as to form an artificial rock or baſe for the pier; theſe ſtones will by degrees ſink into the ſand, and being followed by others, theſe will reſt upon the former, and ſo on till the firſt or loweſt part becomes at reſt; for the ſand laying very cloſe and compact underneath, will bear any weight when not affected by the action of the ſea.

In this method a much greater quantity of ſtone will be needed than if the pier was built upon a regular baſe; but the whole of the baſe being of rough ſtones, the more irregular the better, of which great plenty may be got from the neighbouring rocks; as the whole will be done without timber work, and a large quantity of rough ſtones that would be needed to defend the timber work will be avoided, or rather compoſe a part of, and be included in the propoſed ſcheme, it will upon the whole not only be much cheaper, but when well ſettled, more ſecure than any thing can be made upon a foundation of piles and timber upon the ſand.

Upon theſe principles I propoſe to raiſe the pier to half tide, or even to the top, according as the materials are found to turn out; the principal uſe of this pier being a breakwater, or defence againſt the ſea, the uprightneſs or lining of the inſide for the purpoſes of a quay are leſs material; nor is it probable that it can be uſed for this pur-

 poſe,

pofe, as the fpreading of the irregular ftones at the bottom will prevent veffels from laying clofe home to the pier.

Having carefully viewed the feveral places from whence ftones are likely to be got, and conferred with Mr. RICHARDSON, mafon, who affifted me in this furvey, upon the probable expence of winning, moving, and placing the fame in order, I have accordingly formed an eftimate of the probable expence, as follows.

ESTIMATE for building a Pier in the harbour of *St. Ive's* of 60 fathoms in length, according to the plan and fketch accompanying the fame.

The higheft fpring tides being 26 feet above the furface of the fand, the pier fhould be carried up folid at leaft 30 feet above the fame, and fuppofing the whole to fettle into the fand 6 feet, the whole height will be 36 feet, and admitting the fides to batter half the height of the pier on each fide, and to be 24 feet broad at top, the bafe will be 60 feet, and the mean breadth 42 feet, or 14 yards; this multiplied by the height, 12 yards, produces an area or fection of 168 yards in each yard running.

It is fuppofed that a pier built in the manner propofed with a parapet, regularly walled with *Aberthaw* lime, will be done at the price of 6*s.* 6*d.* per cube yard; but as the quantity of fettlement into the fand is not quite certain, with other contingencies fufficiently to allow for thofe, I eftimate the whole at 7*s.* 6*d.* per cube yard, and this for 168 yards fection, come to 63*l.* per yard running.

	£.	s.	d.
To carrying out the pier 120 yards, at 63*l.* - - - -	7560	0	0
The parapet to be 9 feet high, 7 feet bafe, and 3 feet top, the mean thicknefs will be 5 feet, and contain 5 yards fection, which, at 7*s.* 6*d.* per yard cubic, is 1*l.* 17*s.* 6*d.* per yard running, and which for 120 yards is, - - - - - -	225	0	0
To extra work in finifhing the pier head, cramps, iron, and lead, - - -	200	0	0
	£. 7985	0	0

J. SMEATON.

Aufthorpe, October 25, 1766.

TOPCLIFF MILL.

The REPORT of JOHN SMEATON, Engineer, upon the Practicability of removing *Topcliff* Mills, *Yorkshire*, to *Assenby* Stream, below *Topcliff Bridge*, consistent with the proposed navigation of the river *Swale*.

HAVING viewed the situation of *Assenby* stream, as also the present situation of *Topcliff* mills, I am of opinion as follows:

1st. That exclusive of the dam, which is totally ruined, the mill appears to be in bad repair, and built upon so bad a principle for doing business, as to be incapable of any considerable improvement, without intirely rebuilding.

2d. That the situation of *Assenby* stream is preferable to the present one, as there may be a better fall.

3d. That supposing the mill and dam to be entirely rebuilt, the only difference, in point of expence, in the present situation, or at *Assenby* stream, will be in the carriage of the old materials from the old situation to the new one, and in digging the cut at the new situation, and perhaps some additional charge about the mill stable and out parts of the mill-house, which, in its present situation, might possibly be saved.

4th. That the removal of the mill and dam will be equally if not more beneficial to the navigation at *Assenby* stream, than in its present situation, because it seems to me, that a dam raising the water 7 feet, or thereabouts, at *Assenby* stream, will pen the water up to the same level of the present mill, as it has ever been penned by the dam before it was destroyed; and by building a dam at *Assenby* stream, the navigation dam below needs not he raised so high as it otherwise must be, in order to float the vessels over the shoal at *Assenby* stream in dry seasons.

Northallerton, 14th March, 1767. J. SMEATON.

EYMOUTH

EYMOUTH HARBOUR.

The REPORT of JONN SMEATON, Engineer, upon the Harbour of *Eymouth*.

THE harbour of *Eymouth* lays at the corner of a bay, at which ſhips can work in and out at all times of tide, or lay at an anchor ſecure from all winds, except the northerly or north-eaſterly. From this circumſtance its ſituation ſeems very advantageous; but as the mouth of the river or harbour lies open to the northerly winds, ſhips cannot lay in ſafety therein without going up beyond the elbow of the preſent quay, where the water being ſhallower by ſeveral feet, and the breadth much contracted, the harbour is not only defective in point of capacity, but in ſafety alſo; for at a full ſea the mouth being wide, the ſea tumbles in with ſo much impetuoſity, that great ſeas find their way round the elbow, and make the veſſels even there lay not ſo quiet as is to be wiſhed; in order therefore not only to enlarge the harbour, but very greatly to increaſe the ſafety of veſſels laying therein, it is propoſed to build a north pier to defend the harbour's mouth, and to this end nature has furniſhed a ledge of rocks, not only capable of making the moſt excellent of all foundations for ſuch a pier, but in as advantageous a ſituation as could be wiſhed, upon which a pier is propoſed to be built according to the plans accompanying this report; for, according to the directions therein ſpecified, the harbour will be defended from all ſuch ſeas as annoy the bay, and the only point from whence the harbour could be affected by ſeas coming in through the mouth, are land-locked by the points of the bay; ſo that the harbour will, in its whole extent, be perfectly ſafe in all winds. It is alſo to be noted, that the ſame circumſtances that concur to make the harbour ſafe in all winds, afford the veſſels means for getting in and out at all winds *: and this proceeds from the entry into the harbour laying nearly at a right angle with the di-

* 1ſt. If the wind is right a-head to veſſels coming into the bay, it will of courſe be ſmooth water, and there being room enough to turn, they can work in till they are near the bottom, and then ſail with a fair wind right into the harbour. 2d. If a veſſel comes into the bay before the wind with a great ſea, ſhe will alſo have the wind fair to ſail into the harbour. 3d. If the wind is right a-head to her going into the harbour, ſhe will have a fair wind into the bay with ſmooth water, ſo that after coming to an anchor, ſhe can warp herſelf in. 4th. In like manner a veſſel that wants to go out, if the wind blows right into the bay, ſhe will have a fair wind out of the harbour, and having room in the bay, can work herſelf out to ſea, unleſs it blows ſo hard as to bring on a great ſea, and if ſo it would be undeſirable to be out at ſea upon a lee-ſhore. 5th. If the wind is right a-head to a veſſel deſiring to go out of the harbour, as the bay will be ſmooth, ſhe can warp out, and being out, has a fair wind out of the bay. Laſtly, a veſſel going before the wind, out of or into the *harbour*, will have a fair wind out of or into the bay reſpectively; and a veſſel going before the wind, out of or into the bay, will have a fair wind out of or into the harbour reſpectively.

rection into and out of the bay; it is alſo a great advantage that here is a good flow of tide, which at ſpring tides is ſaid to be 20 feet, and there is at the loweſt ebb ſeveral feet of water at low water between the propoſed pier-heads, ſo that there will be ſeldom leſs at neap tides than 16 or 17 feet water in the harbour, which is capable of receiving veſſels from 300 to 400 tons, according as they are more flat or more ſharp built, and which afterwards can, upon a greater flow of tide, be got into a more advantageous birth.

Another advantage to the executing the propoſed deſign, ariſes from a great quantity of rough rocks that lay at the north-weſterly point of the bay, very proper for building the outſides of the body of the pier, the inſide of which may be done with rough ſtones won or blaſted from the neighbouring rocks to that upon which the pier is propoſed to be built; by this means the pier may be executed at a trifle of expence, in proportion to the extent and utility of the deſign; for the rocks that are repreſented within the intended pier will be removed and made ſmooth, ſo as to procure an addition of harbour-room, at little or no charge, as they will be uſed within the pier: when this is done, there will be an addition of harbour-room in the ſpace between the elbow before-mentioned and the pier-heads, capable of holding 30 ſhips of middle ſize, with ſufficient paſſage, and which in time of war will be very uſeful on this coaſt, not only for the refuge of coaſters from the enemy, but in bad weather for privateers and the ſmaller ſized veſſels acting offenſively.

What relates to the method of the work itſelf, will be ſufficiently explained by the plans and eſtimate; I have only to remark, that I do not mean to fix the place of the pier to ſuch preciſion, as not to be ſubject to be ſomewhat varied.

If it is found convenient, on account of fixing the baſe, to be a little more in, or a little more out, or the head ſomewhat nearer or further from the preſent head, than ſpecified in the plan, I expect the ſurveyor to uſe his judgment therein.

Alſo I don't mean that the ground courſe of the ſtones forming the baſe of the pier ſhould be exactly in a right line, or the baſes cut to the ſame level, or anſwerable to any given delineation lengthways of the pier; all I deſire is, that a bed be cut for each ſtone declining towards the middle of the pier, as ſhewn in the plan, but they may be upon different levels, and a little more in or out, as beſt ſuits to get a firm footing for each particular ſtone, which ſtones muſt be ſuited in their ſizes and thickneſs accordingly.

In regard to the repairs of the preſent pier and quay, where it is neceſſary to begin at the bottom, I adviſe to drive a row of piles 6 inches in thickneſs, and cloſe together,

edge

edge and edge, and the heads being connected by a ſtring piece, to let the ground courſe of ſtones be notched upon them as was done at *Coldſtream Bri ge*. The reſt of the quay will be defended by laying a tier of rough ſtones, ſloped up againſt it at the foot, but not ſo as to be in the bilgeway of the ſhip.

This would be ſtill more effectually done by driving a row of piles either cloſe together, or at moſt but 9 inches diſtant from one another, and at about a yard diſtance from the foot of the pier, ſo as not to be in the way of the veſſels, and to lay a ſlope of rubble ſtones againſt the foot of the pier, between the pile heads and the wall, as before deſcribed, obſerving always to ſlope the rubble down ſtream. This I think the beſt way of ſecuring the preſent quay; but as it will be altogether defended from ſea-ward by the propoſed pier, and as the laſt propoſed defence muſt be attended with ſome expence and trouble, being only to be done at ſhort intervals of the tide, I adviſe to cut the matter of repair ſhort by laying ſtones only, and take a trial of this till the north pier is built.

Auſthorpe, May 2, 1767. J. SMEATON.

ESTIMATE for *Eymouth* Harbour. The expence of building a north pier.

The length of the outſide, from the elbow and round the head into the flank within, is 240 feet, this multiplied by 22 feet mean height, produces 5280 feet ſuperficial, and this by 5 feet mean thickneſs, produces ſolid - - -	26400 cube feet.			
The length within, from the elbow to the ſaid flank, is 132 feet, which multiplied by 22 feet high, is 2904 feet ſuperficial, and by 3 mean thickneſs, gives -	8712			
Total ſolidity of the firſt ſtretch next the head,	35112			
It is ſaid, that ſuch works as are repreſented in the inſide can be brought from the rocks and laid in place at 6*d*. per foot, but as I underſtand this of the looſe rocks already quarried, and as the quantity ſo produced may be ſhort of the whole, and the quarrying is ſuppoſed to coſt 2*d*. per foot extra, therefore, to make a ſufficient allowance, I make 7*d*. per foot on the whole: the outſide, the workmanſhip will be more rough, but the ſtuff being ſuppoſed larger, and worſe to place and handle, I reckon on that alſo 7*d*. per foot,		£.		*d*.
To 35112 cube feet of ſtone in the outſides, at 7*d*. - - - - -		1024		
The whole circumference being 372 feet, this multiplied by $3\frac{1}{2}$ feet mean breadth of the baſement courſe, produces 1302 feet ſuperficial, this quantity of the rock will be required to be cut ſloping towards the middle of the pier, and being tide-work, and the rock hard, I allow				
To 1302 feet ſuperficial of rock cutting for baſement, at 8*d*. - - - - -		43	8	0
The length of the above being 173 feet, the mean width 24 feet, and mean height	feet			
22 feet, the whole content, in ſolid, will be - - - - -	91344			
From which, deducting the outſides, - - - - - -	35112			
Remains for the ſolidity of the inſide filling which is equal to 2083 cube yards.	56232			

Carried forwards 1067 10 0

		£.	s.	d.
Brought forwards,		1067	10	0
To 2083 cube yards (after deducting the outſide blocks) of filling with rough ſtones *, to be placed by hand, and well packed, at 4*s.* per yard, - - - - -		416	12	0
To 172 feet length of parapet, mean thickneſs 6 feet, and 9 feet high, produces 344 yards ſolid, which being well walled and filled with mortar, and built of free-ſtone rubble, I allow 7*s.* 6*d.* per cube yard, - - - - - - - - -		129	0	0
To hammer-jointing and facing both the outſides, containing 3268 feet ſuperficial, at 1*d.* -		13	12	4
The cordon, being 172 feet long, and $2\frac{1}{2}$ feet in breadth, and 1 foot thick, will contain ſolid - - - - - - - -	430			
The capping, being 174 feet long, 3 feet broad, and 1 foot thick, will contain -	522			
Sum	952			
To 952 feet of *Leimerton* ſtone, worked, and laid in place, at 1*s.* - - -		47	12	0
To flooring for the top of the pier, being 172 feet long, and, at an average, 6 feet broad, containing 1032 feet ſuperficial of the ſame ſtone as the outſide of the pier, at 8*d.* -		34	8	0
To ſtone poſts for mooring, - - - - - - -		5	0	0
For 173 feet of pier next to and including the head, - - - -		1713	14	4
The length of the pier, from the elbow to *Gunſgreen Point*, being 181 feet, upon a mean height of 13 feet, the ſuperficies will be 2353 feet on each ſide; and allowing the mean thickneſs on the outſide 4 feet, and the inſide $2\frac{1}{2}$ feet, the mean thickneſs of both ſides will be $6\frac{1}{2}$ feet, and the whole ſolid formed thereby 15295 cube feet, at 8*d.* - -		446	2	1
To 724 feet of cutting the rock for the baſement courſes, which being leſs in the tide's way, I reckon at 6*d.* - - - - - - - - - - -		18	2	0
The outſide blocks being deducted from the ſolid contents, there remains for filling 1046 cube yards, which being more out of tide's way, I eſtimate at 3*s.* - - -		156	18	0
To free-ſtone rubble walling in the parapet, being 8 feet mean baſe, $2\frac{1}{2}$ mean top, and $7\frac{1}{2}$ mean height, contains 264 cube yards, at 7*s.* 6*d.* - - - -		99	0	0
To hammer-jointing and facing both the outſides, containing 2896 feet ſuperficial, at 1*d.* -		12	1	4
To hewn work of *Leimerton* ſtone in the cordon and parapet, the cordon being $2\frac{1}{2}$ feet broad, and the parapet the ſame, and 1 foot thick; this for 181 feet running contains 905 cube feet, at 1*s.* - - - - - - - - - - - -		45	5	0
To flooring the top of the pier between the parapet and aiſler, the mean breadth being 5 feet, will contain 905 feet ſuperficial, at 8*d.* - - - - - -		30	3	4
To rough ſtones to be laid in the angle of the pier, adjoining the land at *Gunſgreen Point*, -		3	0	0
For 181 feet of pier from the elbow to the point, - - - -		810	11	9
For 173 feet ditto next and including the head, - - - - - -		1713	14	4
Sum		2524	6	1
For contingent expences I generally allow 10 per cent. upon the whole, - - -		252	8	7
		2776	14	8

N. B. As the rocks within the pier head will be got and made uſe of in filling the pier, I ſuppoſe this to be included in filling of the pier; but if fender piles ſhould be thought neceſſary within the pier for veſſels to rub againſt, the expence of thoſe muſt be added.

* All ſtones in the filling are propoſed to be put in whole, unleſs they ariſe of above two tons.

STONEHOUSE CREEK BRIDGE.

METHOD of conſtruction of the Bridge over *Stonehouſe Creek*, as deſigned by JOHN SMEATON, Engineer.

ON the *Stonehouſe* ſide of the bridge there appears, from the borings and ſoundings made by Mr. JOHN MUDGE, to be a good hard clay bottom, which gradually declines from the quay towards the middle of the creek, but which at the further ſide of the channel at low water is 20 feet deep below the mark of low water ſpring tides; from thence for a ſpace of 250 feet, that is till within about 80 feet of the oppoſite ſhore, the clay bottom can no more be felt with ſounding rods of 26 feet long, which were the length of thoſe made uſe of, ſo that for the aforeſaid ſpace of 250 feet the depth of the mud is not known; but from the manner in which it declines from each ſide, it is not unreaſonable to ſuppoſe it to lay ſomewhat like the line dotted out in the plan, but whether this be ſo or not, the depth of the mud is aſſuredly ſo great, that to found the whole upon piles would be ſo very expenſive, as to render the conſtruction in that reſpect impracticable. It is therefore propoſed by removing the water-way about 50 feet nearer the quay than it now is (that is, the middle of the arch to be about 100 feet diſtant from the quay) to take the advantage of the riſe of the clay bottom, in order to found a couple of piers whereon the arch may ſolely depend, and to make the reſt of the paſſage over the creek by forming a rampart with rubble ſtone, and quarry rubbiſh caſt upon the ſurface of the mud, and heaped upon till the ſtones firſt caſt, either ground themſelves upon the clay bottom, or by conſolidating the mud by mixing therewith, ſhall make an artificial foundation capable of ſuſtaining the incumbent weight of materials above the ſurface of the mud; for this purpoſe, the piers of the arch being built ſquare on the outſides next the ramparts, and quite upright, no ſettlement of the rampart will affect the piers, nor will any of the work of the ramparts be diſplaced in ſettling by encountering with any projection of the piers, nor will any damage enſue to any part of the work by ſuch ſettlement, but what may be reſtored by addition at the top; and as there is plenty of rubble to be obtained on the ſide next *Plymouth Dock*, a conſiderable part of which would have been neceſſary to have been removed for the ſake of forming a proper ſlope for the road up the hill, it is expected that this rampart may be formed at a moderate expence. The work of the rampart may be begun immediately; I will therefore firſt deſcribe the manner in which I would propoſe to carry it on, ſubject nevertheleſs to ſuch alterations as difference of circumſtances ariſing from the proceſs of the works ſhall indicate.

I would

I would propofe then to begin at the end where the matter is to arife, bringing forwards the materials in wheelbarrows or carts as fhall be found moft convenient, merely to tumble them over the creek, obferving to referve the heavieft and beft ftones for the outfide, the fecond beft for the bottom, and the rubbifh for the middle: I would advife to carry forward the work to its full height nearly as it advances, by which means the whole will obtain its full fettlement in the leaft time. The breadth at top, and flopes therefrom, being as per fection, the feveral widths at the furface of the mud, will be had by confulting the outermoft ground lines of the plan; and as the work will begin from the fhore, the additional width to begin with, in order to allow for fettlement into the mud, will be found by experience as the work goes on.

The fection of the rampart fhewn in the defign being adapted to the line *A B*, near the middle of the prefent channel, and fuppofing it to ground upon the clay bottom there, the beginning ought to be 72 feet wide, as therein fhewn.

When the work is advanced fome diftance from the fouth-weft fide, and the mud grows deep, if it is found to fwallow up a greater quantity of matter than is expected, it will be proper, by way of making a kind of bond or platform for the bafe, to ftake down a double thicknefs of fafcines or faggots upon the furface of the mud, and then proceed to throw the ftones upon it, as is reprefented in the fection; this will be not only a likely means of keeping the bafe from fpreading as it goes down, but of producing an equilibrium fooner, in cafe it fhould not be found to go to the bottom where the mud is deep.

When the core of matter is found in fome meafure to come to reft, in order to get the proper breadth at top, it will be neceffary to begin at the furface of the mud, and difpofe the larger materials by hand, fo as to form the flope or batter fhewn in the fection, which is nearly that of $\frac{1}{3}$ of the perpendicular above the furface of the mud, and is fuppofed to be the flope of an equilateral triangle below the fame.

With refpect to the founding of the pier, as the deeper will be near 10 feet below the low water fpring tides, I apprehend it will be quite impracticable to get down to the clay without incafing; I therefore would propofe to encompafs a fquare area, capable of juft containing the bafe of each pier, with a fingle row of dove-tailed piles, of 4 inches in thicknefs, to be driven a foot or 18 inches into the clay, more or lefs, as they are found to go harder or eafier, and of a fufficient height to keep out the neap tides; that is, about 16 feet long, the heads of them to be regulated at top by ftrong pieces within, and fupported by beams acrofs, which may alfo be done in one or two tier below, as

ſhall be found neceſſary to ſupport the preſſure; which lower beams muſt be made moveable, and taken away as the work advances.

The mud below its ſurface will render the piles water-tight, and if not found ſo above, may eaſily be made tight, by throwing in ſome baſkets of coal aſhes, cloſe to the piles on the outſide, when the water lays againſt them.

As I do not expect the bottom to be level, it muſt be reduced thereto by forming one or more ſteps, as ſhall be found moſt convenient, obſerving to form the flat of the ſteps rather inclining towards the hill; and unleſs the matter happens to be ſo hard, that the piles cannot be drove therein full 18 inches, I would have the ground courſe next the water-way of the arch, and the returns thereof, laid at leaſt 1 foot below the natural bed of clay, that the gulling of the water (which will ſoon carry away the ſoft matter down to the clay) may not eaſily get under the foundations of the piers.

When the firſt pier is raiſed ſufficiently above low water mark, the piles may be drawn, and made uſe of in like manner for the other; and if there appears to be the leaſt danger of the gulling of the bottom by the water, I would adviſe a part of the piles, of which the dam has been formed, to be cut to a proper length, and placed in the groove already formed, ſo as to be driven down, or cut off below the ſurface of low water ſpring tides; this to be done in the face of the piers, next the water-way, and the returns of the angles, but to the remaining parts of the piers it will be uſeleſs.

As this buſineſs will be tide-work, except at neap tides, it will be neceſſary to procure one or more good chain pumps, in order that the cavity may be expeditiouſly cleared of water; it will be adviſeable to have a couple of upright ſquare pumps, of about 8 inches, (as they will ſtand in leſs room) to keep the water out after the bulk is evacuated, and for the ſtanding of which an upright groove or receſs may be formed in the back ſide of the piers; I adviſe two, that one may be in order, while the other is cleaning or repairing.

The arch, the facings, cordon, and capings, I would propoſe to be of *Portland* ſtone, the ruſtic part of the pillars of *Moor* ſtone, the body of the parapet over the arch of *Plymouth* marble, cut aiſler, the ſpandrills of the arch of the ſame, either courſed or rough, as may be thought moſt proper, and the body of the piers below the ruſtic may be aiſler'd, either with *Plymouth* marble or *Moor* ſtone, as may be thought proper on account of price; but if no great difference, I would adviſe *Moor* ſtone, as taking more kindly to the mortar, eſpecially where conſtantly wet. The whole of the inſide core I propoſe

propofe to be of rubble from the neighbouring rocks. It will be advifeable to fet the whole outfide up to high water neap tides with *Watchet* or *Aberthaw* lime, and it would, as *Plymouth* lime is very tender in water, be alfo very advifeable that a quantity of the aforefaid lime was procured to mix with that of *Plymouth* for the infide work to high water fpring tides: this is the more neceffary, as *Plymouth* lime and marble do not feem difpofed to form of themfelves a very compact body, when conftantly fubject to the water.

Not having a plan of the quay at *Stonehoufe* and houfing adjacent, I have drawn the bridge ftraight; but as it may probably be found more fuitable and convenient to make the rampart fomewhat curved from the arch and termination upon the quay, I leave this to the determination of thofe concerned in the execution upon the place.

The above is, I think, the moft material of fuch directions as at prefent occur, and which I hope will be found fufficient for beginning; if any thing is not fufficiently explained, fhall be ready to do it by letter.

J. SMEATON.

London, June 15, 1767.

LINTON DAM AND SWALE NAVIGATION.

The REPORT of JOHN SMEATON, Engineer, upon ſundry points relative to the *Linton* Dam and Swale Navigation, referred to his conſideration by JOHN SMITH, Engineer for the ſaid works; by order of the Commiſſioners.

The points were the following:

1. WHETHER any, and what allowance may be made for the declivity of the rivers *Ouſe* and *Swale* in dry ſeaſons, ſo as to depend on making a depth of water beyond the dead level of the height of the dam.

Anſwer. It is the practice of engineers in levelling to allow one inch per mile for the leaſt ſenſible current, and this I apprehend may be ſafely allowed, but not more; I don't mean that there can be no current, under an inch in a mile; but that all methods of levelling are ſo precarious, where ſuch minute differences are concerned, that it is as ſafe to make that allowance as to rely upon any other method to prove it, eſpecially as it is eaſy in practice to remedy the defect by adding a rib of wood to the crown of the dam, in caſe its height ſhould be found defective by a few inches.

2d. Whether the height of 11 feet above the ſurface of low water at *Linton* is neceſſary for the dam there above that ſurface, in order to make good the water to the mark near *Milby Staith*, which, according to his levelling, he makes to be 11 feet above the ſaid low water ſurface at *Linton*.

Anſwer. The difference of 11 feet between the mark at *Milby*, and the low water at *Linton*, is preciſely the ſame that I made it; which I particularly remember, having explained it to the committee in *London*, how I came to expect to raiſe the water to my propoſed height at *Milby* by a 10 foot dam at *Linton*, obſerving that the diſtance being eight or nine miles, according to the common allowance of an inch per mile, that would make ſo many inches, and the remainder would be made by the thickneſs of the ſheet of water going over the dam. I ſtill remain of opinion, that, for the ſame reaſons, if the dam at *Linton*, its crown is raiſed within one foot of the dead level of the propoſed point at *Milby*, that the water will riſe to its mark, at leaſt ſo as it may be helped by a rib of wood as beforementioned, it being impoſſible to take levels with abſolute certainty for

ſo

ſo great a diſtance. It is however to be remembered, when my plan was originally projected as above, the *Linton* dam was ſuppoſed one undertaking with the *Ure*, and being no more than a general deſign to ſhew the practicability, the utmoſt accuracy was not wanted; but as it may prevent any jealouſy between the different parties intereſted if the *Linton* dam is raiſed within half a foot of the dead level of the mark at *Milby*, I think it cannot fail to raiſe the ſurface of the water in its drieſt ſeaſons to its mark at *Milby*.

3d. Whether the deſign prepared by Mr. SMITH for the dam at *Linton* is a proper one for the purpoſe.

Anſwer. The deſign exhibited is I apprehend upon the ſame principles as that at *Naburne*, but with improvements; and as that at *Naburne* has ſtood the teſt for ſeveral years, I cannot doubt but this will do the ſame if executed with the ſame care and judgment. It would ſeem to me to be more unexceptionable if the baſe was enlarged by 6 feet, and the top diminiſhed by 6 feet, the loweſt ſtep to be raiſed 2 feet above low water, and the aſcent from thence to the top to be divided into three equal ſteps inſtead of two. The greateſt objection I have to this conſtruction regards expence. It is greatly different reſpecting the body of the dam from what I propoſed, and with the principles of my propoſed conſtruction; but I have acquainted Mr. SMITH, where the reputation of an artiſt is concerned in the ſucceſs of his works, he certainly ought to proceed upon his own ideas, and not thoſe of another. This is certain, had the navigation been opened before the *Linton* lock and dam was begun, which was the declared preliminary of my original eſtimation, in order to bring down ſtone from above for the conſtruction thereof, that it would have been erected at a much leſs expence; as it now is, it may be a matter of computation into which my preſent occaſions will not permit me to enter.

4th. Whether the deſign for *Linton* lock is properly adapted.

This lock is I apprehend upon the ſame conſtruction as I have ſeen ſeveral by Mr. SMITH's father built ſeveral years ago, and which have ſtood and anſwered very well; the principal articles, in which I differ in grounds where I uſe wood bottoms, are the following.

1ſt. A bearing pile under each ſill, ranging in the face of each wall, (but this is rendered leſs neceſſary by a ſheet of piles, in Mr. SMITH's conſtruction, under the face of each wall;) a ditto under each ſill anſwering the middle of the chamber, and if the ground is more ſoft, a pile under the outward end of each ſill.

2d. The

2d. The great ſill for the lower gates, the pointings framed therewith under the threſholds, in order the more firmly to be bolted thereto.

3d. A double row of rabbeted piling at the lower gate ſill to prevent the paſſage of the water in caſe the chamber-floor ſhould become defective.

4th. The coffin ſtones made alternately long and ſhort, broad and narrow, in order to prevent their walling joint and joint, as it ſeems to me muſt be the caſe if made of one dimenſion, as preſcribed by Mr. SMITH.

5th. In good gravel bottoms, where ſtone is cheap, I have uſed it inſtead of wood, ſtill keeping a row of piles under the face of the walls, with a ribband or ſtring piece upon their head, two good rows of rabbeted piling under the lower gate ſills, and a row of ditto at the tail of all.

The maſonry of the lock in general ſeems well deſigned, and ſubſtantial; but after all deſigns, good execution is a great matter.

KNOUCH BRIDGE MILL.

Proportions and directions for building the Mill at *Knouch Bridge*, by JOHN SMEATON, Engineer.

THE two water-wheels for common uſe to be 11 feet 6 inches diameter, out and out, and 8 feet wide, the ſhrouds to be 9 inches above the ſoal, and to have 36 buckets, the riſing boards to be $4\frac{1}{2}$ inches broad, and the breadth of the bucket-board ſuch, that the point of one bucket may advance to the center line of the heel of the next bucket, and the cutting edge to be thrown to the outſide.

The bucket-boards ſhould not be of above 1 inch in thickneſs, and to ſtrengthen them, I recommend a ſhroud in the middle; the conſtruction I commonly uſe in wheels of this ſort, is three pair of claſp arms with three rings, and then to put on the boarding of the ſoal parallel to the axis, ſo that the boards are nailed down upon the rings ike a floor upon joiſts. The wheel caſe or race to be made to a true ſweep, anſwerable to the wheel, to be continued from the loweſt point under the axis for a quarter of a circle, ending at the height of the center, above which the breaſt wall to be continued upright to a proper height for ſupporting the trough, which, if thought proper, may be made of ſtone to the front of this breaſting. The water in taking the wheel ſhoots backwards, ſo that the wheel turns the ſame way round, and the water is delivered at the tail, as an under-ſhot wheel; the water is drawn by two ſhuttles, anſwerable to the partition ſhroud in the middle of the wheel; but as it is impoſſible to deſcribe the particular form of the trough, ſo far as relates to the drawing on of the water, without a draft, this ſhall be ſupplied in due time.

The water-wheel being 11 feet 6 inches diameter, there will remain 2 feet to compleat the whole difference of 13 feet 6 inches; the whole height required for the ſurface of the water above the top of the wheel being only 1 foot 6 inches, there will remain 6 inches either to be added to the head of water, or to admit the bottom of the wheel to be laid 6 inches out of tail water, or to be expended partly one way and partly the other, according to the judgment of the artiſt.

Nos. for the two over-ſhot wheels.

The great cog wheel - - - -	64	at $5\frac{1}{2}$ inches pitch.
The great lanthorn upon the upright axis -	25	
The ſpur-wheel upon the upright axis -	72	at $3\frac{1}{4}$ inches pitch.
The 5 foot greyſtone lanthorn - -	19	
The 4 foot cullens or blue ſtone - -	15	
The 3 foot $10\frac{1}{2}$ *French* ſtones - -	14	
The 3 foot 7 inches cullens or blue ſtones -	13	
The 5 feet greyſtone for ſhelling oats, its lanthorn	15	

N. B. The numbers above being put upon the ſpindles of each pair of ſtones reſpectively, and all being *ſuppoſed* to be placed round the ſpur-wheel, they would all go at their proper paces if driven together: therefore they may be ſuited together to either mill, as beſt ſuits the convenience of the miller.

For the flood-mill, it being propoſed to remove one of the preſent water-wheels from the *Whiſton* old mill, which are 14 feet 8 inches diameter in the ring, I propoſe to continue the ſame number of floats as at preſent, but to alter the mortices, ſo that the ſtarts may hold the floats pointing to the center.

The float-boards to be 1 foot broad, and ſo as to form a circle of 17 feet 4 inches, the reſt of the ſpace to be filled up by oblique breaſt-boards like the wheels at *Kilnburſt* forge; but ſhall ſhew the particular degree of obliquity, by a draft along with the trough for the over-ſhots.

The width of the wheel may continue the ſame as at preſent, viz. 5 feet 2 inches, but if it can conveniently be augmented to 6 feet, it will be the better.

The flood-wheel I propoſe to be a breaſt-wheel, and to be laid 7 feet below the full head, viz. the noſe of the gate to be when ſhut 2 feet below head, and 5 feet fall; now as this will make the bottom of the flood-wheel 6 feet or $6\frac{1}{2}$ feet above the common tail-water, and as this wheel will do buſineſs with 3 feet or $3\frac{1}{2}$ feet tail-water, it follows, that it will do buſineſs when this river is from 9 to 10 feet higher than in its ordinary ſtate.

The

The numbers propofed for this wheel as follows:

The great cog wheel	- - -	84 cogs	at a 5 inch pitch.
The greateft lanthorn on its upright axis	-	25	
The fpur-wheel on the upright axis	. . . - -	72	at a $3\frac{1}{4}$ inch pitch.
A pair of 5 feet grey ftones	- - -	19	
A pair of 4 feet cullens	- - -	15	

N. B. If any other forts or fizes are thought proper, the numbers or the fpindle lanthorn will anfwer, if made refpectively the fame as thofe for the over-fhot wheels.

The over-fhot mills above propofed will both be turned at once, with the fame quantity of water wherewith one of the wheels of *Whifton* old mill was worked when I was there, and which was faid to be about the whole quantity in dry feafons. This quantity will enable each of the over-fhot mills to grind with great eafe at the rate of a quarter of wheat per hour, that is 16 *Winchefter* bufhels per hour by the two wheels.

The breaft-wheel will grind the fame quantity as either of the over-fhot wheels, but will require a double quantity of water, that is, it will require as much water to grind eight bufhels per hour, as both the two over-fhot wheels will require when grinding at the rate of eight bufhels *each*; but as the two over-fhot wheels will work at the rate abovementioned with the common fummer's water, I apprehend it will feldom happen but there will be water to fpare, and therefore it may be worth while to confider whether one of the over-fhot wheels may not be omitted, and the breaft-wheel ufed in fhort water times in its ftead, and by that means the breaft-wheel be brought to act in a double capacity, as a fhort water wheel as well as a flood wheel.

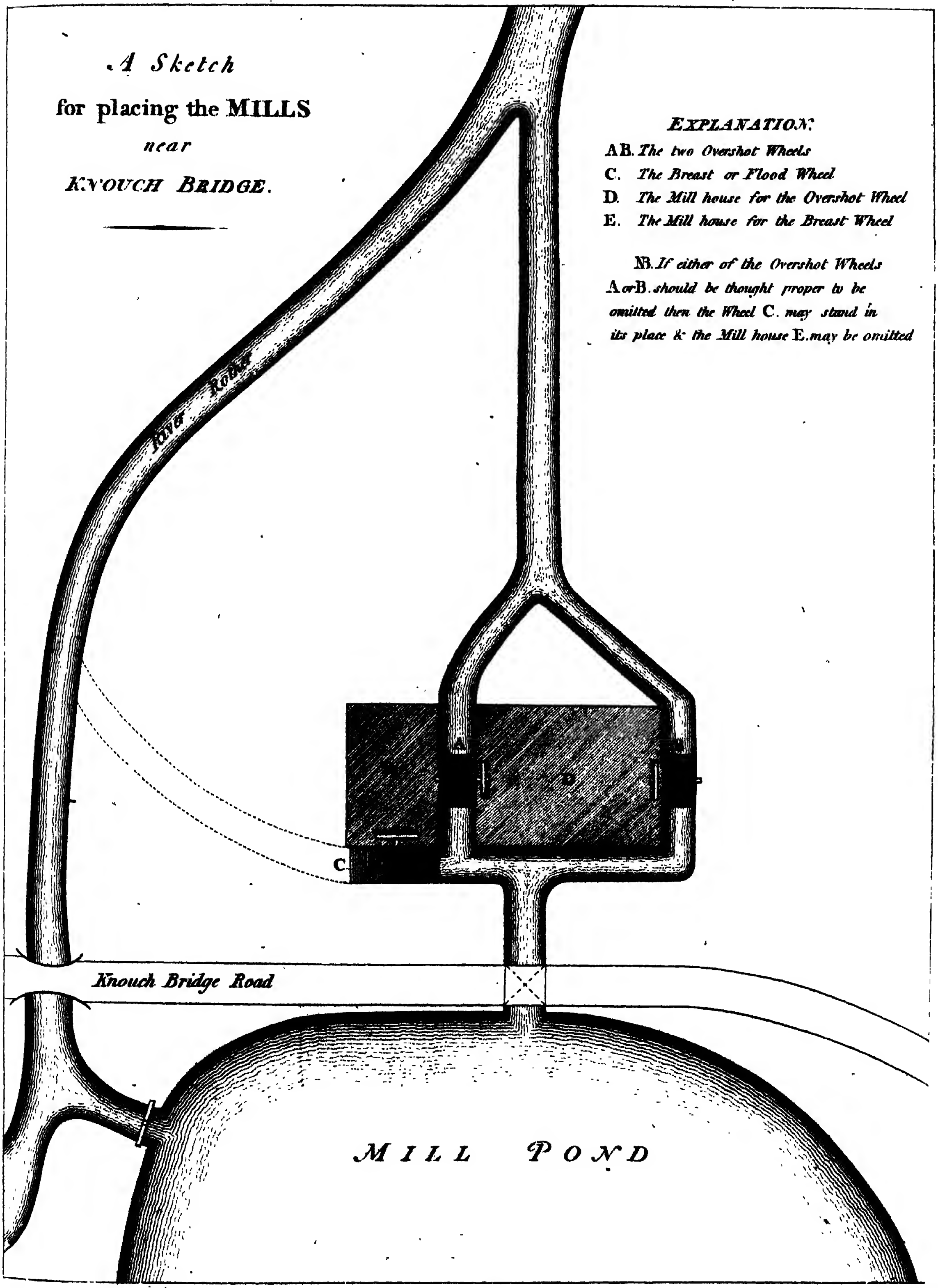
The over-fhot wheels will work with 3 or 4 feet tail water, at which time there will be neceffarily fuch plenty, that it will be very immaterial whether the breaft-wheel takes more or lefs.

London, 15th June, 1767. J. Smeaton.

N. B.

P. S. If the ſtaves of the great lanthorns are made of caſt iron, as will be adviſe-able, they may be made of a flattiſh or oval figure, and thinner than if made of wood, ſo as to give room for a ſtronger cog.

The following ſketch reſpecting the ſituation will, I hope, make the whole clear.


A Sketch
for placing the MILLS
near
KNOUCH BRIDGE.
EXPLANATION.
AB. The two Overshot Wheels
C. The Breast or Flood Wheel
D. The Mill house for the Overshot Wheel
E. The Mill house for the Breast Wheel
NB. If either of the Overshot Wheels
A or B. should be thought proper to be
omitted then the Wheel C. may stand in
its place & the Mill house E. may be omitted
River Rother
C
Knouch Bridge Road
MILL POND

RIVER COLN.

PLAN for aſcertaining the proportional quantities of water flowing down the high ſtream and *Iver* ſtream, being two diviſions of the river *Coln* below *Uxbridge*, from whence alſo may be determined the quantity of water diſcharged at each place per hour.

THE ſketch annexed is ſolely explanatory to ſave many words in deſcription, and is thereſore ſuppoſed not to be drawn from a ſcale.

The point A ſhews that branch of the river which comes from under the weſternmoſt bridge of *Uxbridge*; this is not the whole of the river *Coln*, a conſiderable ſtream being diverted therefrom, called the *Cowley* ſtream, which croſſes the great weſtern road nearer the body of the town.

Below the point A the branch in queſtion divides, one part turning the water-engine or colour-mill, and ſeems to have been an artificial cut, but the greater part of the water goes down the old river; thoſe ſtreams unite at B, and are again divided at C into two ſtreams, called the high ſtream and *Iver* ſtream, the former being much the largeſt; from the point of diviſion C the water runs with a gentle current to the bridge D, where, meeting the ford where the road croſſes, and being ſomewhat pent up, it runs more rapid from thence to E, where this branch ſubdivides, but afterwards unite and join with the ſtream beſorementioned.

From the point C the *Iver* branch runs with a very languid current till it meets the iſland F, after which it runs more briſkly, as alſo at the bridge and ford at G it runs again languid till it gets into the incloſures, and then more briſkly through the incloſures till it gets to the ſecond bridge at H, where there is a further obſtruction and fall, and from thence it runs to *Iver* mill.

Now, if a water-gage is erected upon the high ſtream, and another on the *Iver* ſtream at any place ſo far below the point of ſeparation at C, that the water running from C to D, and from C to G, ſhall not be interrupted in its natural courſe, then thoſe water-gages will reſpectively ſhew the proportion of the two ſtreams, and afford a means of computing their real quantities, independent of any enquiries or evidence to be collected from the millers, and which may be executed in the following manner: Upon the branch of the high ſtream E L, and near the point L, let a water-gage be erected of

N. B. The water-courſe I R ſeems intended to diſcharge the overplus water in times of floods from the Iver ſtream into the high ſtream, the mouth of the paſſage at I being ſtopped up with piles.

30

30 feet in width, the fill whereof to lay even with the common furface of the water in dry times, to be terminated by two upright pofts, and if need be, one in the middle, fo to divide the fame into two paffages of 15 feet each, the whole to be made clofe and tight underneath the fill and on each fide the pofts, fo that no water may pafs during the ufe thereof but through the 30 feet paffage over the fill, and confequently will fall over the fame like a tumbling-bay. While this is erecting, the water may be turned through the paffage E M, which will go to the mills as at prefent, but when compleated, the water, being ftopped from going through E M, will wholly be obliged to pafs the water-gage at L, and will raife the water there fo little as not to affect the run of the water from C to D. Now, as the *Iver* ftream runs more languid than the high ftream, it will be neceffary to go fomewhat lower down, fuppofe to the bridge H, a little above which at N let a fimilar gage be erected, but with this difference, that as the *Iver* ftream is not fuppofed to be above half the currency of the high ftream, a gage of 15 feet will equally carry the water. As this width will not occupy the whole river there, the gage may be erected on one fide, while the water let down to the mills on the other fide, and being compleated, the bye paffage muft be ftopped up, and the whole of the water be obliged to pafs the water-gage, as in the other.

Now, upon turning the water through the two gages, if the depth of the current water upon the fill is equal, then the quantity will be in proportion to the widths; that is, that the currency of the high ftream is double the currency of the *Iver* ftream; but as the depths at firft trial will probably be found unequal, let as many boards be put into that gage (end-ways up) upon which the water runs *fhallowest*, as by ftraightening the water-way will caufe it to run of equal depths with the other, then will the proportional quantities be as the widths refpectively, when fo adjufted, and this will be fhewn by infpection, according to the various ftates of the river in dry feafons, whether the mills are drawn or not, and the experiment may be continued (with a proper attendance) for a month, or fuch time as fhall be thought neceffary; and account being kept of the depth of the water at different times, anfwerable to given widths, will afford a means of computation of the real quantity in tons per hour; but the computation of the real quantities is more matter of curiofity than ufe in the prefent cafe, for as the propofition is to take away no more water from the confined ftream at A, than is due to the *Iver* ftream, in any one given ftate, therefore more efpecially in the loweft ftate, it will follow, that if the whole river at A was afterwards parted by a gage, fimilar to thofe in the experiments, whereof that reprefenting the *Iver* gage is conveyed to *London*, and the other to be conveyed down the high ftream, after the *Iver* ftream is ftopped up by a dam, then will the high ftream remain with its prefent quantity of water as heretofore, nor will it be furcharged in time of floods for want of paffage down the *Iver* branch; becaufe, whenever the river at C rifes fo high, as to afford more water than the

the mills can uſe, the ſtop or dam upon the *Iver* being made in the form of a tumbling-bay, the ſurcharge will be conveyed down the *Iver*, and for ſeveral months in the year will be a conſiderable running ſtream.

It will be neceſſary alſo to put a ſmall gauge upon the little brook that falls into the *Iver* at the bridge C, which, when reduced to the ſame depth, muſt be deducted from the width of the gauge at N, and the width ſo reduced, in compariſon with the gauge at L, will give the true proportion of the ſeparation of the waters at C, and of the propoſed ſeparation at A. Again, as a quantity of water is propoſed to flow down the *Iver* ſtream, in order to ſupply the neighbouring meadows, villages, and the town of *Colnbrook* with water, whatever the aforeſaid little brook ſhall exceed or fall ſhort of what ſhall be thought proper for that purpoſe, a due allowance can be made in the width of the gauge propoſed to be erected at A.

It may be objected, that when the water due to the *Iver* ſtream is deducted from the river at A, that then the engine or colour-mill will loſe a proportionable quantity of water; but as the water flowing down the main ſtream is not employed in working any mill before this reunion, if, in dry ſeaſons, the main river is ſtraightened, in the ſame proportion by a flood-gate to be erected at O, and to be drawn up in times of floods, then will the engine or colour-mill be in all reſpects in the ſame condition it now is

It may a ſo be obſerved, that the obliging the river to paſs the water-gauges at A, may, in floody ſeaſons, pen the water upon the tail of the mills juſt above the bridge of *Uxbridge*; but as this *partition* will only be of uſe in dry ſeaſons, it is propoſed that there ſhall be a ſet of flood gates, that being drawn up, ſhall leave the river as capacious as it is at preſent, and, conſequently, the mills in the ſame condition; it is alſo propoſed, that the water-gauge at A ſhall not be erected ſo as in dry ſeaſons to pen up the water above the bridge of *Uxbridge* higher than it now is, ſo that the mills above the ſame ſhall not, in any ſeaſon, be affected by the propoſed undertaking. It is ſuppoſed, that this method of the partition of the water is (if poſſible) more unexceptionable than that of taking a given quantity out of the river or colour-mill head near A, as formerly propoſed; but that if this method be thought more eligible, as the gauges abovementioned will afford a juſt method of computing the real quantity of water diſcharged by the *Iver* ſtream, a quantity may be taken by the method already exhibited, which ſhall

never exceed the juſt proportion in the drieſt ſeaſons, and in all others rather fall ſhort than exceed it, and ſtill the ſurpluſage, when too much for the mills and grounds, be diſcharged by the *Iver* ſtream in the ſame proportion as heretofore.

Auſthorpe, July 8, 1767. J. SMEATON.

PORT GLASGOW PUMP.

DESCRIPTION of a Pump for the dock at port *Glasgow*.

THE water left in the dock at a medium to be evacuated by pump-work, as taken the 22d day of August, 1767, was

Mean length	-	243 0	Solid contents 21141 Cube feet = $627\frac{1}{2}$ tons.
Mean breadth	-	36 0	
Mean depth	-	2 5	

This quantity to be raised in 4 hours to the mean height of 4 feet will require 6 men working at a time, and good *English* labourers, will continue at the same rate for the whole time; but as the labourers to be employed will probably be such as can be promiscuously picked up, it will be proper to have two sets to relieve each other.

The distance of the chains from the axis of the lever to be $\frac{1}{7}$ of the length of the lever; it would be most convenient to have the center of the chains 2 feet from the center of the lever, but should not be less than 1 foot 6 inches.

The diameter of the working barrels to be 17 inches; and it would be well to have them lined with cylinders of hammered brass or copper, as iron will rust in salt water, and the bare wood will chamber too fast.

In the working of this pump it is to be noted, that when the height of the water without exceeds the height of delivery, that it will never rise higher in the mounting pipes above the chamber than just to force its way outwards, so that the water will never be raised to any height that is unnecessary, and with a proportional addition of force will throw out the water at all times of tide.

The 2 barrels A B are connected together by a square box or trunk C D, into which are 2 square passages through the working barrels E F, about 8 inches high by 10 or 12 inches wide; in the foreside of the box is an hole $10\frac{1}{2}$ diameter, so as to receive a pipe of $8\frac{1}{2}$ or thereabouts, which pipe is to be rammed tight, and to lay through the wall or bank into the open sea, the outward end of which may be guarded by a valve if thought necessary; but if the lower valves of the pump are tight, no water can revert into the dock; it will indeed rise to an equal height in the mounting pipes, but will there be at rest.

 The

The buckets I would propoſe to be made in the ſame way as thoſe for fire-engines, and the lower valves to be made double; I propoſe them to be framed upon a caſt-iron plate, cloſing up the bottom of the barrel, and which may be ſcrewed to the barrel by 6 or 8 bed-ſcrews, the nuts of which to be let ſideways into the wood.

H H H H are blocks for the pumps to reſt upon.

The iron rods and buckets will, I expect, be of weight ſufficient to carry them down, but they ſhould be ſteadied by paſſing through a plug or collar in the top of the mounting pipes.

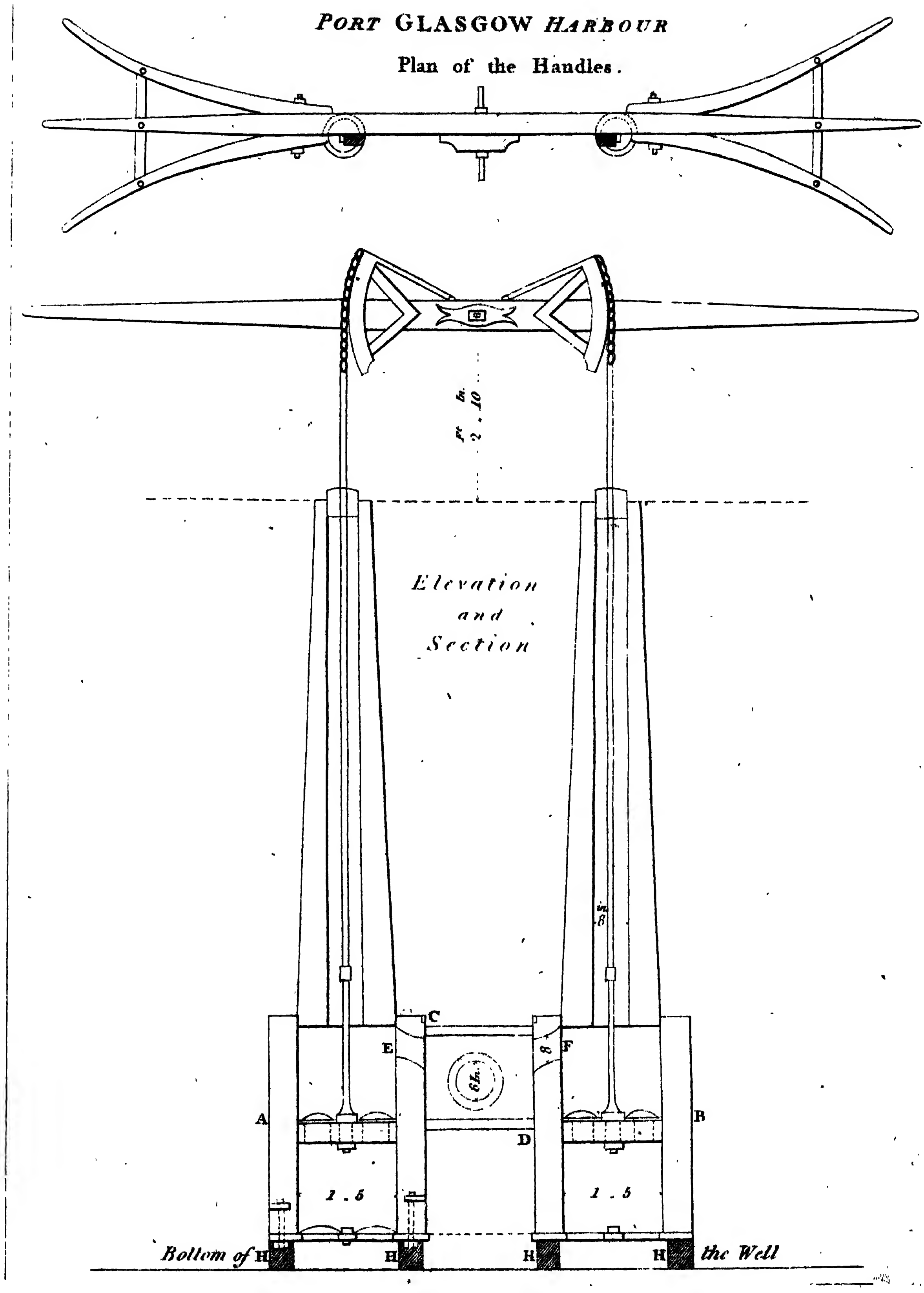
The valves muſt be made light, particularly of the buckets, that they may meet with the leſs check in deſcending, and the whole leathered with pliable leather, which will be fully ſufficient for a column of ſo ſmall a perpendicular.

If the employment of 12 men for 4 hours be thought too much, this work may be done in 3 hours 20′ by 2 ordinary horſes, the pumps being contrived upon the ſame * principle, and 3 pumps to be worked by a triple crank, the proportions as follow:

Diameter of the working barrels		1 foot
Length of the ſtroke - - -		3 feet
	No.	
Lanthorn on the crank ſpindles	19	cogs at $4\frac{1}{2}$ inches pitch
Face wheel for driving ditto	84	cogs at $4\frac{1}{2}$ inches pitch
Mean diameter of the horſe-tract -		21 feet

Auſthorpe, 4th September, 1767. J. SMEATON.

* That is not to lift the water above four feet at low water, and no higher than to overcome the reſiſtance from without, at all other times.


PORT GLASGOW HARBOUR
Plan of the Handles.
ft in
2 , 10
Elevation
and
Section
in
8
C
E
F
8
8 In.
A
B
D
1 . 5
1 . 5
Bottom of H
H
H
H the Well

RIVER TRENT.

The REPORT of JOHN SMEATON, Engineer, concerning the Water-Road propofed to be carried acrofs the valley of the river *Trent* from *Mufkham* to *Newark*.

THE points relating to the road abovementioned, referred to my confideration by the truftees thereof, at a meeting on the 19th day of December ult. were as follow:

1ft. The propriety of the choice of the ground for the new road.

2d. The proper height of the road in refpect of the water-line at the extreme of high floods.

3d. The proper quantity of water-way for the neceffary paffage of the water acrofs the faid road in time of the faid floods.

4th. The particular places where the arches ought to be fituated, and the number and dimenfions of the arches proper at each particular place.

5th. The beft method of conftruction of the faid arches, fo that they may be done at as little expence as poffible, confiftent with their being effec al.

6th. The proper fection of the road where it paffes through the grounds to be ramparted.

Thefe are the propofitions as I underftand them, being verbally delivered.

1ft. I am of opinion, that the ground marked out in the plan for the track of the new road is very properly chofen, being in general over the higheft grounds, and fufficiently ftraight; and I look upon it to be an advantage that the arches will be as much as poffible together.

2d. I apprehend that, to prevent damage to the road by its being overtopped, it will be advifeable to make up its crown or fummit to the height of 1 foot above the refpective water-line at the extremes of floods; and the top of the road being convex about 6 inches,

6 inches, the ſides of the road will then be about ſix inches above the ſaid water-line, which height above the water-line will alſo be neceſſary on account of the ſettlement, even after finiſhed, though conſolidated in the beſt manner practicable while making.

In order to aſcertain the reſpective heights of the road above the ſurface of the ground, a point at *Newark Bridge* was ſhewn me by Mr. HANDLEY, as that to which the higheſt floods were never known to riſe, and which has not been touched theſe 30 years: from this point I took a level to a mark at *Muſkham Bridge*, ſhewn me by a perſon of *Muſkham*, as the point to which the ſaid floods aroſe; from whence it appears that at a medium of two operations the flood-mark is lower at *Muſkham Bridge* than that at *Newark Bridge* by 17 inches; and though this medium differed 5 inches from the extremes (which difference of the two operations was the reſult of carrying the level 3 miles) yet it is probable it is very near the truth, as it differs but 1 $\frac{1}{2}$ inch from the level put down upon Mr. WILKINSON's plan in the middle of Lord MIDDLETON's lands, between No. 18 and 19, near *Muſkham Bridge*. The level of the high water mark upon the bridge itſelf was ſhewn me by a different perſon from him that ſhewed the high water mark to Mr. WILKINSON, therefore they probably are not the ſame; and I have reaſon to believe, that from that part of the bridge having been repaired ſince the great flood abovementioned, the point ſhewn me was at leaſt 6 inches lower than the real height of the great flood referred to, ſo that the fall of the water's ſurface from *Newark* to *Muſkham Bridge* will be reduced to about 11 inches. I have driven piquets near the courſe of the propoſed road, between the two bridges, to the places of which the numbers in red refer upon the plan; and having given, by a ſection of the tract of ground, the reſpective depreſſions of the ſaid picquet heads below the water-line, upon a ſuppoſition of 11 inches fall of the water's ſurface between the two bridges, this will be a ſufficient guide for the laying out and forming the road.

3d. The proper quantity of water-way cannot, as it ſeems to me, be determined upon any fixed principles, becauſe it is very difficult, if not impoſſible, to determine exactly what proportion of water in great floods runs over the ſurface to that which runs through the two bridges; all that can be done, therefore, is to make the beſt eſtimation we can, rather erring by allowing *too much*.

It happened ſomewhat luckily on this head, that I paſſed between the two bridges in a boat at the very higheſt of the great flood which happened on the melting of the ſnow in February, 1766. I then remarked the height of the flood by a fixed mark, to which on this occaſion I referred, and found that the ſurface of the water was then within 6$\frac{1}{2}$ inches of the height that was now ſhewn me at *Muſkham Bridge* as the higheſt of all. I

alſo

alſo then took particular notice of the quantity of water flowing through the rails, gates, and void ſpaces in the hedges, and conſidering the great depth of the river in its own channel, and the great obſtructions the flood waters met with in paſſing the hedges from wreck, &c. depoſited therein, I cannot in my own mind ſuppoſe that the whole water paſſing over the ſurface of the lands could equal that which paſſed through *Muſkham Bridge* alone; but, that we may err on the ſafe ſide, let us conſider the capacity of both bridges. Having, on the preſent occaſion, taken dimenſions of the water-ways of both bridges, and compared them with the length of the arching that will be equivalent thereto, upon a ſuppoſition that the flood arches upon an extreme flood carry a depth of water upon their floors of 6 feet at a medium, I find them as follow:

	Yards running.
Muſkham Bridge equal to flood bridging —	154
Newark ditto — — — —	99
Equivalent of both bridges in flood bridging	253

In order to check the above, I took an eſtimatory account of the whole openings in the line of the hedge on one ſide the preſent road through which all the flood waters muſt paſs that run over the ſurface of the lands, and make them amount to an equivalent of flood bridging of 333 yards.

Now the mean of the two determinations will be 293 yards, but for a round number let us ſay 300 yards, which is near ⅕ more than the ſum of the capacities of both bridges: now this quantity, properly diſpoſed of, will, in my opinion, be amply ſufficient for diſcharging the flood waters, without the leaſt danger or detriment of either the lands above the road, or to the road itſelf; and if the expence ſhould make it needful, I am of opinion that the quantity above mentioned may be retrenched.

4th. The next article is the proper diſpoſition of the arching above mentioned; and on viewing the face and levels of the country, it appears that the places where the flood-bridges now are, viz. at *Crankley*, and the three bridges, are the principal outlets for the flood waters. This experience has taught our forefathers, as is manifeſted by their placing bridges in thoſe places; it follows therefore that thoſe natural hollows, which lead the waters to thoſe points, will be the propereſt places for the new flood-bridges, at the ſame time diſpoſing of ſome arches or tunnels quite through the whole, to prevent any water remaining pent between the hedges in any particular place.

 The

The arches I would recommend are of 12 feet wide, and 6 feet from the floor to the ſpringer; they may be nearly all alike, except that in ſuch places as will admit thereof, the floors may be laid lower, and the piers raiſed higher above the foundation than before ſpecified, in order that one with another they may be of 6 feet depth of water; for leſſer communications, I would propoſe tunnels of 5 feet width, covered by ſemicircular arches, the depth from the crown to the floor to be 6 feet, and the crown of the arch on the under ſide to be 2 feet 6 inches under the crown or ſummit of the road. According to theſe dimenſions, three of theſe tunnels will be equivalent to one of the arches.

The places of the arches and tunnels as follows:

			Extent in clear water-way.	
	Arches.	Tunnels.	Yards.	Feet.
In the low ground between the north end of *Newark Bridge*, and the higher grounds oppoſite the warehouſe, - - -	9	0	36	0
In Mr. Ridgell's cloſe, - - - -	2	2	2	2
In Thomas Wood's ditto, - - - -	0	1	1	1
In James Hanker's, - - - - -	0	2	2	2
Croſs the valley at the three bridges - - -	24	0	96	0
The further hollow in Mr. Stevenson's cloſe, where the piquet, No. 8, is placed, - - - - - - -	0	3	4	0
In the drivers, where the piquet, No. 12, is placed, - -	0	1	1	1
In the great hollow from the drivers to *Langdale*, croſſing the water-courſe that leads to *Crankley Bridge*, - - -	24	0	96	0
In the low ſlade in the rector of *Kelham*'s ground at No. 16, -	6	0	24	0
In the croſſing of the old road, - - - -	3	0	12	0
In Lord Middleton's land, near the ſouth end of *Muſkham Bridge*,	3	0	12	0
Between *Muſkham Bridge* and the high land at the north end thereof,	3	0	12	0
	72	9	300	0

The above is the beſt diſpoſition I can form for the placing of the water-ways from my own obſervations and the information I have had; but as the going away of the preſent ſnow may probably furniſh a good opportunity of making obſervations upon the currency, it would not be improper to appoint a diſcreet perſon for that purpoſe. I am opinion, however, that if the arches in thoſe two places, which are laid out for 24 arches each, were reduced to 21, the water-way would be very ample.

5th. With reſpect to the conſtruction of the arches, having explained myſelf by a deſign, I have the leſs to ſay thereon: it is neceſſary however to obſerve, that reſpecting

the

the foundations, I have ſuppoſed it a firm gravel or clay, at the depth to which it will be neceſſary to excavate; but where it proves a ſoft clay, looſe gravel, or ſand, or ſtill ſofter matter, it will be neceſſary to pile under the piers. In ordinary caſes, piles from 5 to 8 feet long, and from 6 to 8 inches diameter, driven about 2 or $2\frac{1}{2}$ feet diſtance, middle and middle, will ſuffice; but as nothing can be aſcertained on this head, without trial of the individual ſpot of ground in queſtion, and as the firmneſs of the ground will frequently vary one pier from its next neighbour, the quantity and ſize muſt be increaſed or diminiſhed, at the diſcretion of the ſurveyor.

Where piles are not uſed, I propoſe the firſt courſe of bricks to be ſet edgeways upwards, the length of the bricks croſſing the baſe of the pier, the whole to be driven down with a paviour's rammer in the manner of a pavement, and after that the interſtices run full of grout or putty, or if wet, to be filled with quick lime. If piles are uſed, bricks or half bricks to be drove down in the ſame manner in the interſtices between the pile heads, and then to begin the regular courſes upon the paving and pile heads promiſcuouſly, being grouted as before. It is hardly neceſſary to ſay, that where a good foundation can be come at by going deeper, at a leſs expence than piling, it will be proper to do it.

As the arches are propoſed to be but 12 feet wide, in order to avoid an unneceſſary quantity of brick work, I have ſuppoſed the ſhafts of the piers to be but $2\frac{1}{2}$ bricks thick, which, if built firm inſide and out, will be very ſufficient to carry the loads in ſuch ſhort ſpans; the arches themſelves I have ſuppoſed to be no more than one brick thick, which I am alſo ſatisfied, if well done with good materials, will be quite ſufficient: yet, as the ſupporting parts in the elevation have ſomewhat of a light appearance, if to ſatisfy the eye the truſtees think it proper, half a brick may be added to the piers, and alſo half a brick to the arches within, which will make but little alteration in the deſign.

To ſave expence, I have ſuppoſed the whole to be of brick, the cap ſtones for the terminating pillars of the parapet excepted, which are neceſſary to be of ſtone, on account of weight to keep on the brick caping; but if the expence can be admitted, it would give the whole a more ſubſtantial appearance to thoſe who travel the road, to have the whole caping of ſtone. I ſuppoſe that the ſhoulder angles and ſpringers of the piers, together with the capings, if of brick, to be made of their proper figure in moulds for that purpoſe.

To make all the piers thick enough to ſupport all the adjacent arches *ſingle*, without the counterbalance from the neighbouring arches, would bury a large quantity of ma-

 terials;

terials; I have therefore adopted the thought of my ingenious friend Mr. MITCHELL, in making every third pier or every fifth ſtrong enough for this purpoſe, that in caſe of accident the damage may not be progreſſive.

6th. In regard to the proper ſection of the road, it appears from the general ſection, that the flat ground from the point No. 4, to the three bridges, is the deepeſt flooded of any part that will be done by ramparting, and that the depth at a medium below the water's ſurface is 4 feet, the mean height therefore of the crown of the road will be 5 feet; and for this height a ſection is drawn, ſhewing the excavations neceſſary on each ſide, in order to furniſh matter to form it when conſolidated; but if the bottoms of the canals on each ſide do not afford gravel for a cover, then the excavations may be of leſs width on account of this part of the matter being brought from a diſtant place; but whatever be the height of the rampart, the ſame ſection will regulate it, by ſuppoſing the top of the road and angle of the ſlopes on each ſide to remain the ſame, and therefore the width only of the baſe to be variable, according to the quantity of matter required.

I ſuppoſe that in a few years the ditches will ſilt and graſs over ſo as to become paſture land, but as it will not only be unavoidable, but in ſome meaſure uſeful for the water, in time of great floods, to have a current along thoſe ditches, it will be proper, as early as poſſible, to ſow them with hay ſeeds, to prevent their ſides from ſlipping, or from being galled by the current while they are new.

In order to prevent the ſurge, which in time of great floods will be raiſed by the action of the wind from waſhing down the ſides of the rampart before it can get firmly ſwarthed over, it will be neceſſary to ſet the ſlopes of the ramparts with ſods, in the manner ſhewn in the ſection; and if the ſlope of the ditch next the rampart, as well as the oppoſite ſide where it faces the arches, was ſodded alſo, it would be ſtill better.

I have drawn the ſection of the road ſo as to afford a breadth of 30 feet for the tread of the wheel, which I apprehend will be quite ſufficient, eſpecially where the rampart is raiſed high, as well as in the bridging; but in the high grounds, where the road is to be but little raiſed, it will not be neceſſary to be confined to this width.

Auſthorpe, January 11, 1768. J. SMEATON.

GLASGOW

GLASGOW BRIDGE.

Copy of a REPORT delivered at *Glafgow* by Mr. SMEATON, in October, 1760, from a copy thereof received from Mr. MURDOCK in a letter, dated April 20, 1768.

" Report concerning the fituation of the intended new bridge over the river *Clyde* at *Glafgow*."

HAVING carefully examined the river at feven different places, viz. 1ft, oppofite *Jamaica Street*; 2d, at the middle of the ifland, commonly called *Ducat Green*; 3d, in a line paffing behind the *Gorbal* church; 4th, in a line agreeing with the ftreet that runs before the *Gorbal* church; 5th, at the prefent bridge; 6th, at the flaughter-houfe, in a line with the new ftreet; and 7th, at the *Green* of *Glafgow*, almoft oppofite to the gate leading from the bottom of the *Salt-Market*, of which a particular account is contained in the paper annexed, from whence it appears to me that the fituation of the prefent bridge is not the moft eligible, for the following reafons: 1ft, On account of the greatnefs of the length which will increafe the expence; 2d, by the ftreet anfwering thereto on the *Gorbal* fide being too narrow, and embarraffed for the main avenue to a bridge of 30 feet wide; that ftreet being not above 22 feet at a medium, and in feveral places not 18 feet; 3d, becaufe it would not be fafe to build a new bridge in the fame place, except conformable with the old foundations, which would fubject the new bridge to great irregularities; for as the prefent bridge appears to be founded upon the furface of a cruft of gravel, covering mud or fleech to an unknown depth, was the new foundation upon the interftices, and the old ones removed for the fake of giving a free paffage to the water, as this cruft is undoubtedly broke through in many places by piles, &c. it would be dangerous to remove them, left, by giving advantage to the fpeats to gull away the ground from thence, a free paffage is given to the mud to efcape, and thereby to render the new pier liable to fettlements. 4th, The difadvantage of wanting a bridge during the time of building a new one, or the charge of a temporary bridge balanced againft the fmall value of the old materials, are too obvious to need infifting upon. 2d, The pofition agreeing with the front of the *Gorbal* church is not the moft eligible on account of the great length between the top of the bank on each fide, fo that it would require the extent of the bridge to be greater than its prefent fituation; and as the north end would abut upon the workhoufe dyke, would be too near, and too confined, without an opportunity of forming any new ftreet in any good direction from thence, nor is the

the avenue from the ſouth abutment free from objections, being but 27 feet in the wideſt part, and not above 19 oppoſite the church wall, which would require to be removed, and ſome private property purchaſed; nor is the croſs ſtreet leading to the turnpike leſs exceptionable.

3d. The poſition agreeing with a line paſſing behind the *Gorbal* church, will clear the ſouth abutment of all incumbrances, and mend the north in regard to the practicability of making an opening into the green beyond the row of trees called the *Old Green*; but till that is done will be as much confined as the former, nor will this ſituation admit of any ſtreet in any good direction into the town, without paſſing through gardens and private properties; add to this, that here the bridge will be required the longeſt of all, the diſtance from the tops of the banks being upwards of 600 feet.

4th. To the poſition agreeing with *Jamaica Street*, are the following objections: the bottom is worſt of all, and the water deepeſt, nor does the line of this ſtreet produced cut the ſtream at right angles, which is a diſadvantage that ought always to be avoided if poſſible; but without inſiſting on any objection to this ſituation on account of its being too near, and too much confining and embarraſing the preſent wharf or landing-place, or on account of its being too far removed from the preſent bulk of inhabitants, the foundation is a matter of conſequence, for though the mud or ſleech that lies under the bed of gravel is much of the ſame conſiſtence as above (if any thing more ſoft), and may be made capable by proper care and caution of bearing the ſuperſtruction of a bridge; yet as the upper cruſt is conſiderably thinner, and leſs compact than above, it is juſtly to be apprehended that when the channel comes to be contracted by the piers, the increaſe of velocity of the water, in time of ſpeats, may take away the bed of gravel between the piers, and by laying the mud expoſed to the action of the water, may produce fatal conſequences upon the adjoining piers, and this cannot be prevented but by a conſiderable addition of expence in the original conſtruction, in piling, ſetting, and framing the whole of the ſpaces between the piers.

5th. At the ſlaughter-houſe, in a line with the new ſtreet, the river is of a moderate width, the running ſand below the gravel lies the cloſeſt I ever met with at that depth; yet as the upper ſtratum of gravel is but looſe, and the under cruſt very thin, this foundation is not without ſuſpicion on account of the ſpeats, nor does the line of the new ſtreet make a right angle with the ſtream of the river; ſo that after pulling down ſeveral houſes in order to open an avenue thereto, the direction of the bridge cannot properly ſtand in a continued line with the ſtreet; the avenue on the ſouth ſide will alſo be embarraſſed in paſſing the *Gorbals*, for after pulling down ſome houſes to make an avenue anſwerable

anſwerable to the croſs ſtreet leading to the turnpike on *Paiſley* road, that ſtreet itſelf is in many places not more than 16 or 17 feet wide.

6th. The foundation at the green at *Glaſgow*, oppoſite the gate leading from the *Salt-Market*, is much the ſame as at the ſlaughter-houſe; the objection with reſpect to a paſſage through the *Gorbals* the ſame; the avenue from the bottom of the *Salt-Market* might be ſomewhat enlarged, by removing the garden wall, but the clear between the houſes in the narroweſt place is not more than 25½ feet.

7th. It now remains that we examine the poſition at or near the middle of the *Ducat Green*; the width of the river between water and water is leaſt of all, being at the boiler 345 feet, and from the top of the bank on the ſouth ſide, to the top of the high ground on the iſland, 495 feet; from that point meaſuring acroſs the *Green*, to the middle of the road down the avenue of trees, is 180 feet; from the top of the bank on the ſouth ſide, to the *Paiſley* road in a direct line through the arable ground, 600 feet, which, allowing the breadth of the road to be 40 feet, will ſcarcely amount to half an acre *Scots*: in this poſition the new bridge will be about 900 feet diſtant from the preſent bridge, unembarraſſed at either end, and capable of joining a new ſtreet that might hereafter be made acroſs the *Old Green*, which may be made in a right line upon an arable cloſe, and join the *Troangate-Street* near to Mr. Buchanan's houſe, without interfering with any preſent buildings or gardens. The obliquity of the ſtream of the *Clyde* with the line will indeed occaſion the poſition of the bridge not to be in the ſame line, but the obliquity will not be ſuch as to occaſion any material inconvenience with reſpect to the uſeful part. The foundation at this place, though not perfectly the beſt, is yet as good at bottom as any, and the bed of gravel as thick, and in general as compact as any, but the upper cruſt for about 8 or 9 inches not quite ſo hard as at the ford oppoſite the *Gorbal Church*, and at the preſent bridge, but much more compact than it is lower down; however, to remove all objections on account of the ground, I would propoſe to make the ſum of the openings of the new bridge equal to the ſpan of the river in that place; and conſequently, as the velocity of the water in time of ſpeats would not be increaſed, there is no reaſon for ſuppoſing that the ſaid gravel that now ſuſtains their efforts, will not continue ſo to do; and this may be done two ways, 1ſt, by digging away ſo much of the ſouth ſide of the *Ducat Green* next the river as ſhall be equal to the ſum of the ſolids of the bridge, and with the earth to fill up the back drain; 2d, by ſetting the abutments a little within the land on each ſide, and to procure a further addition of free paſſage by widening and deepening the back drain, over which I would throw a ſingle arch.

The

The former way would be the more eligible, on account of the conveniency of paſſages to the bridge, the latter will in that reſpect be ſufficient, and amply ſo whenever a new ſtreet is made; but I apprehend the latter would better anſwer the conveniencies of trade; for the widening this back drain to 40 feet, ſo as to admit of two veſſels a-breaſt, will admit of a convenient wharf on both ſides, and will have this further effect, that a great quantity of water coming down this back drain in time of ſpeats, would cleanſe the face of the preſent quay, which towards the upper end is almoſt choaked up, ariſing from the main ſtream being chiefly on the ſouth ſide.

It therefore ſeems to me that this ſituation of a new bridge will, upon the whole, be attended with the leaſt inconveniences, be executed at the leaſt expence, ſuit the conveniences of the preſent inhabitants, and favour any improvements that may be made further.

(Signed) J. SMEATON.

Glaſgow, October 20, 1760.

Meaſures, Soundings, and Obſervations made upon the river *Clyde*, relative to the choice of a proper place for the intended new bridge at *Glaſgow*, made the 13th, 15th, 16th, and 17th of October, 1760, by JOHN SMEATON.

	Span of the river water and water.	Slope to the top of the Bray. On the South.	On the North.	Sum.	Depth. Ft.	In.	Qualities of the ſoil in the middle of the river to 10 feet deep.
	Feet.	Feet.	Feet.		Ft.	In.	
1ſt. Oppoſite *Jamaica Street*, - -	384	54	50	488	3	6	3 feet of looſe channel, below mud or fleech.
2d. At the upper boiler on the iſland,	345	100	50	495	2	6	5 feet of good channel, below ditto.
3d. Behind the *Gorbal* church, - -	348	150	150	648	1	6	4 feet of good channel, below ditto.
4th. Before the *Gorbal* church, -	389	68	133	590	1	6	1 foot of hard channel, 3 feet looſer ditto, and mud below.
5th. At the preſent bridge, - -	536	$21\frac{1}{2}$	$28\frac{1}{2}$	586	3	0	1 foot very hard channel, and below ditto.
6th. At the ſlaughter-houſe, - -	360				2	0	3 feet looſe channel, 1 foot hard ditto, below a running ſand.
7th. At the *Green* of *Glaſgow*, -	370				2	0	Ditto.

N. B. The general height of the bank on the ſouth ſide is 13 feet above low water; the height on the north ſide about 9 feet; there being then about 2 feet water upon the hirſt.

WHITEHAVEN HARBOUR.

The REPORT of JOHN SMEATON, Engineer, upon a View of the Harbour of *Whitehaven.*

HAVING carefully viewed the harbour of *Whitehaven* upon the 7th and 8th of April, 1768, I am of opinion as follows:

That in cafe the expence and length of time attending fuch a work would permit its execution, that the nobleft and beft fcheme would be to carry out a north pier, and to lengthen the new pier, till the heads of the two piers fhould be within a competent diftance (fuppofe 200 feet) of each other; but as I apprehend it would be many years before much relief could be procured to the trade by fo extenfive a work, the moft ready way of enlarging the harbour would be by extending the old pier by fome additional works, the particulars of which it will require leifure to judge of; but I am clearly of opinion, that if during the coming fummer the old pier can be lengthened 30 yards, and turned a little more outward than the prefent direction, it will perfectly agree with every juft idea of what is to follow, and that the prolongation aforefaid fhould be the firft work done; and if during this time a correct plan of the harbour, piers, and appurtenances, together with the coaft as far as *Rednefs Point*, is prepared to be laid before me, I fhall then be in a condition to judge more accurately of what is to follow.

Cockermouth, 8th April, 1768.

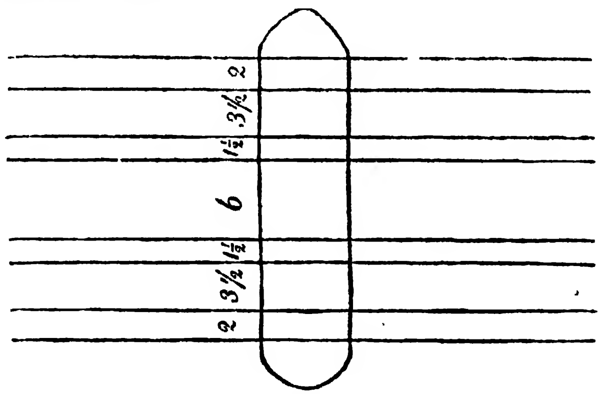
DUMBAR-

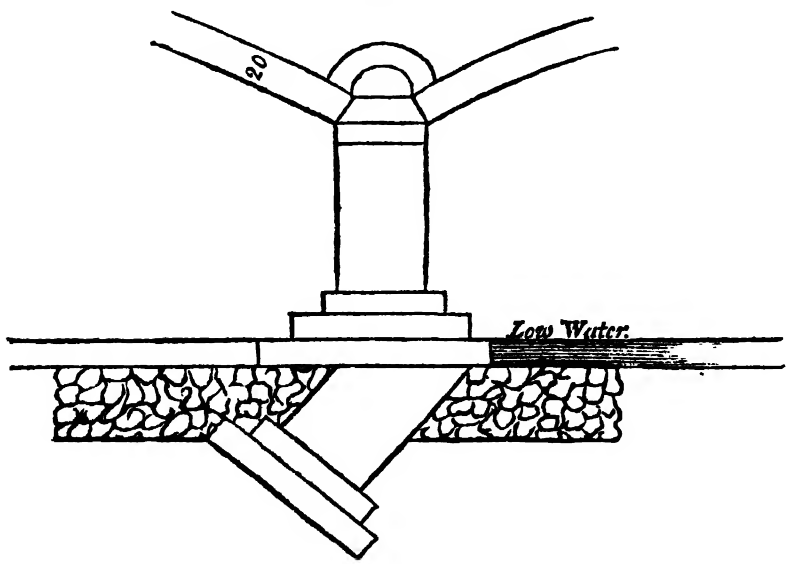
DUMBARTON BRIDGE.

The REPORT of JOHN SMEATON, Engineer, upon the rebuilding the ſunken pier of *Dumbarton Bridge*.

HAVING viewed and examined the ſunken pier of the bridge of *Dumbarton*, and the nature of the ground upon which it ſtands, and finding that it is a ſoft mud to a depth unknown, it being tried to the depth of 46 feet below low water mark, I do not know of any certain method of founding in ſuch a ſituation; but, conſidering the very great difficulty and expence that will probably attend the taking up the preſent work to the bottom, being about 17 feet below low water mark, and the great uncertainty of better ſucceſs, if that could be done, I am of opinion that the beſt probable chance of ſucceſs is to found a new pier upon the ruins of the old, and to make the ſuperſtructure as light as poſſible; the particular methods of doing which I have pointed out to Mr. JOHN BROWN, maſon of the ſaid bridge; and as the other piers and arches ſeem to ſtand firm. I think in the above way there is ſo far a reaſonable proſpect of ſucceſs as to deſerve to be attempted.

Dumbarton, May 31, 1768. J. SMEATON.





LEWES LAUGHTON LEVEL.

The REPORT of John Smeaton, Engineer, concerning the Drainage of *Lewes Laughton* Level, in the County of *Suſſex*.

HAVING carefully viewed and examined the ſtate of this level, upon the 17th, 18th, 19th, and 20th days of June, 1767, I found its condition as follows:

The preceding part of the ſeaſon having proved wet, the level meadows called *Brooks*, laying upon the river *Ouſe*, were in general under water from *Land Port*, above *Lewes*, to *White Wall*, below *Rodmill*. I obſerved that the ſurface of the water in the brooks of *Southover*, *Itford*, *Pool Bar*, *Shine*, and *Rodmill*, was nearly upon one common level, which ſeveral tracts of ground, for the eaſe of expreſſion, I beg leave to call by the general name of the *Weſt Level*: That there was but an inconſiderable fall of the ſurface of the water from the weſt level into the river, when the tide was down, and was ſome inches below the ſurface of the river when the tide was in: the ſame obſervation equally applied itſelf to *Ranſcombe*. That the artificial banks or walls contiguous to the river bordering on both theſe levels, were low, and in very bad condition, ſo that if the river was to ſwell 6 inches higher than it then was, the two levels and river would have one common ſurface. I obſerved, at the ſame time, that the lands below *White Wall*, from the ſouth-eaſt downwards, on the weſt ſide, and thoſe of *Tarring* on the eaſt, were in general dry, and in a tolerable ſtate of drainage, which preferable condition thereof was undoubtedly owing to theſe three cauſes: the land itſelf is conſiderably higher, the banks made up higher, and in better repair; and their out-fall ſluices fixed lower upon the river, which in conſequence affords them a better fall.

It was obſervable during my ſtay, the tides being then in a mean ſtate betwixt ſpring and neap, and the river pretty full of water, that the tides were ſcarcely ſenſible at *Lewes Bridge*, and but a few inches riſe and fall at the mouth of the river *Glynd*; while at the ſheep-waſh above *Piddinghoe*, the tides roſe and fell 5 feet, and not above half a mile below, at the head of the *Broad Salts*, the riſe and fall was near 8 feet; the greateſt part of the whole fall lying betwixt the laſt-mentioned place and *White Wall*, a ſpace not above 2 $\frac{1}{2}$ miles, according to the courſe of the river, and which includes at leaſt $\frac{3}{4}$ of the whole fall, from *Lewes Bridge* to the head of the *Broad Salts*, which is a length of near 7 miles. This great declivity in the river from *White Wall* to the *Broad Salts* is doubtleſs owing to a ſeries of ſhoals laying in that ſpace, the principal of which is *Piddinghoe*, which alone occaſions a fall of 3 feet, and which, as well as the narrowneſs and

winding

winding courſe of the river, altogether occaſion the holding up the water in the river above *White Wall*, and which in conſequence oppreſſes the levels laying thereupon, and ſtill the more in proportion as their natural ſurfaces lay 2 feet at an average lower than the grounds below *White Wall.*

From the head of the *Broad Salts* downwards, the river is more ſpacious and open, and wherein the tides have full liberty to flow and reflow, and may be conſidered as an open tide's way. The declivity of the ſurface at low water is very gentle, till we come near the harbour's mouth of *Newhaven*, where the river *Ouſe* falls into the ſea, and where the water is held up by a bank of ſhingle, thrown in by the great ſeas and tides, and in part waſhed out again by the united force of the freſhes and reflux of the tides, and which finds a balance betwixt theſe contrary powers, being ſomewhat variable according as one or the other happens to have the prevalence. From the ſurface of the water above this bank or bar, that is, from the ſurface of the water in the pool where the ſhips lay, called *Sleeper's Pool*, I found a fall of $6\frac{1}{2}$ feet to the low water mark at ſea, which at ſpring tides is ſtill greater.

The ſtate of the brooks above, or north of *Lewes Bridge*, and which for the ſake of a general name I beg leave to call the *North Level*, was as follows: they were almoſt entirely under water, as high up as *Land Port*; from thence up as high as *Iron Hole*, they were in part under water; but in general where no water upon the ſurface, low and moiſt, and the appearance of being oppreſſed with water a too great length of time; but from thence to *Barcombe* mill, the meadows lay conſiderably higher, being in general 3 or 4 feet above the ſurface of the river, as it then was; however, as the whole courſe of the river through the *North Level*, from *Barcombe* mill to *Lewes Bridge*, has but an inconſiderable fall, is very crooked and winding, and in ſome places obſtructed with ſhallows, the upper as well as the lower part of this level muſt be ſubject to be flooded on moderate down-falls of rain.

With reſpect to the brooks upon the river *Glynd*, eaſtward of *Ranſcombe*, they appeared to be in general above water, but yet ſubject to too great a continuance of ſtagnant water upon them, partly from want of a ſufficient fall in the river *Glynd*, and partly from crookedneſs and obſtructions therein; however, as they appeared in general ſo much higher, that by whatever means the drainage of *Ranſcombe* would be effected, muſt neceſſarily furniſh the means of draining thoſe brooks, I was leſs ſolicitous about the exact ſtate of particulars.

It

It appears moreover, from trying the different depths of the water in the different brooks, that the deepeſt under water were *Ranſcombe* on the eaſt ſide, and the S. E. part of *Itford* and part of *Rodmill* brooks in the weſt level, the general ſurface of thoſe low parts being then about 3 feet under water.

From this general view of the ſtate of the level, it would ſeem, that if the obſtructions ariſing from the ſeveral ſhallows from the narrowneſs and crookedneſs of the river, between the mouth of the river *Glynd* and the top of the *Broad Salts*, were removed, which have been deſcribed to be the cauſe of the holding up of the river at and above the aforeſaid limits, that the conſequence would be a general drainage of all the levels; and it is certain, if theſe things were done, that this alone would be a great help to the whole of the grounds in queſtion; but yet, as the taking away theſe obſtructions would in conſequence let the tides flow in with more rapidity, the natural declivity of the river being ſmall, there would be ſcarcely time for the tide and freſh water to evacuate itſelf, before another tide would return, and thereby prevent its ever running ſo low as to admit of a compleat drainage of the adjacent levels.

Towards an effectual drainage of theſe levels, two methods offer themſelves; one is to ſtraighten the river, and remove all obſtructions as before deſcribed, and furthermore, to prevent the tides from having the effect abovementioned, to place a large out-fall ſluice at its entrance into the open tide's way, with gates to ſhut out the tides from flowing up the river, and of ſufficient dimenſions to diſcharge the freſh waters at their greateſt extream; and laſtly, to embank *Ranſcombe* and the weſt level againſt the overflow of the land floods, ſo as to convey the flood waters directly to ſea, placing ſufficient ſluices upon their reſpective out-falls into the river, ſo as to ſhut out the land floods, and give an opportunity of drainage when theſe floods are run off, which they will eaſily do, when not ſuffered to ſpread upon the adjacent levels; and indeed, without embanking thoſe levels as aforeſaid, every method of drainage will be no more than a palliative help.

The ſecond method ſuppoſes the river to remain in its preſent courſe, or without great alteration, to embank the lands to be drained againſt all extreams of floods, and to convey their internal down-fall waters by a ſeparate canal or ſewer to the open tide's way, with a ſluice upon the out-fall of the ſaid canal, to prevent the reflux of the tides.

Each of theſe methods have their particular advantages; the firſt ſeems better adapted to give all the ſuccour poſſible to the *All Country* dependant on this out-fall; the ſecond is more particularly adapted to the drainage of *Ranſcombe* and the weſt level, the north and

and east levels being less advantageously situated by nature for drainage this way, as will more particularly appear from a further description and estimates that will follow of each method.

From an accurate level taken the 18th and 19th of June last, it appears as follows:

	Feet	In.
Rise from low water to the head of *Broad Salts*, to the surface of the water in the west level,	6	5
The river being then charged with fresh water, the low water surface at *Broad Salts* was said to be 2 feet, at least 18 inches above its low water height in dry seasons, but taking it at - -	1	0
Rise from low water at the *Broad Salts* in dry seasons to the surface of the water in the west level,	7	5
The mean depth of water in the low parts of the west level and of *Ranscombe*, (subtract) -	3	0
Rise from low water in dry seasons at the head of the *Broad Salts*, to the mean surface of the low parts of the west level and *Ranscombe*, - - - - - - - -	4	5
Now in order to produce a compleat drainage of those low grounds, it will be necessary to reduce the surface of the water, below the surface of the ground, - - - -	2	0
There will then remain - - - - - -	2	5

It therefore appears that the water may, in dry seasons, be retained in the river 2 feet 5 inches above low water in the tide's way, and yet the surface reduced full 5 feet below the height it was in June 1767; and as the deepest parts of the pool in *Ranscombe* (which is deepest of all) sounded only 4 feet 6 inches, it follows that the water may be reduced in the drains 6 inches below the bottom of the pool in *Ranscombe*.

In regard to the 2 feet 5 inches of water retained in the river above low water, it will be useful for navigation in dry seasons; and in small freshes, by affording so much fall, will thereby give the river a better current to sea, without overcharging the drains. In larger freshes, and great downfalls, the river's water will be prevented from over-riding the drains by their respective sluices, and the water will quickly discharge itself to sea, on account of its being confined between the banks, which are proposed to be made to prevent the rivers from overflowing the adjacent levels, as they do at present.

To effect these purposes, I would propose a new cut or river to be made across a corner of *Tarring Tenantry*, by which means *Piddinghoe* shoal will be avoided: a sluice is to be placed at the tail of this cut of three passages, 2 of 13 and 1 of 14, containing in the whole 40 feet clear water-way; the latter passage to be furnished with a double pair of pointing doors to seaward, and ditto to landward, for the sake of navigation; the other passages each to be furnished with a single pair of pointing doors to seaward, to shut out the tides, and a single pair to landward, to retain the fresh waters at a given height in dry seasons.

A dam

A dam to be put acroſs the river at *Piddinghoe* ſheep-waſh, ſo as to ſhut out the tides, and to prevent the floods from paſſing that way after the aforeſaid works are erected *.

In order to avoid a crooked part of the river in paſſing by *Itford* and *Stockhouſe*, containing a number of ſhoals, I propoſe to cut a new river from *Stockferry* to the turn below the *White Wall*, of the ſame dimenſions as the former.

All the other ſhoals I propoſe to deepen, ſo as not only to lower the ſurface of the water at *Lewes Bridge* from 4 to 5 feet, but alſo to make full 3 feet 3 inches water over the ſhallows in the drieſt ſeaſons, which will be a great improvement to the navigation, as veſſels will not be ſtopped by neap tides in dry ſeaſons, nor obliged at any time to wait for the tides betwixt the ſea ſluice and *Lewes*.

Theſe works being effected, all the levels in queſtion will be in a *capacity* of drainage, ſo that each performing the particular works that relate to themſelves, the whole will be in a condition of improvement.

As the weſt level and *Ranſcombe* lay conſiderably lower than the reſt, it is impoſſible they ſhould be in a good ſtate of drainage without being embanked againſt the freſhes and floods of the river *Ouſe* and *Glynd*; but inſtead of ſetting the banks cloſe upon the river, I would, in the general, leave a ſpace of 50 feet between the bank and the river, however varying this quantity, ſo that without following the ſudden turns of the river, the bank may be reduced in length; obſerving, that where the bank is near the river on one ſide, it be put further off on the other, ſtill forming an open ſpace to give room for the paſſage of the floods in wet ſeaſons.

According to this method, there will ſtill be a neceſſity of ſluices for the particular drainage of each tract of embanked land, to ſhut againſt the river in time of floods. Thoſe already conſtructed might have anſwered the purpoſe had their threſholds been laid low enough, but as the threſholds of *Shine* and *Ranſcombe* ſluices, which lay the loweſt, are at a medium but about 2 feet below the mean ſurface of the loweſt lands reſpectively, they are inſufficient for an effectual drainage, becauſe before the water can come down to its proper pitch of level for drainage, its thickneſs over the threſholds will be ſo much diminiſhed, as not to afford the water a ſufficient paſſage. I therefore

* It is to be obſerved, however, that if there ſhould happen to be any ſolid objection to putting a dam acroſs the river at *Piddinghoe* ſheep-waſh, that the ſame purpoſe may be effected by putting ſluices, inſtead of a dam at the ſheep-waſh, in which caſe there will need no more than the 14 foot paſſage for the joint purpoſes of navigation and drainage upon the new cut propoſed acroſs *Tarring* brooks.

recommend

recommend a new ſluice of brick for the weſt level, to be placed down as low as the *White Wall*, and another for *Ranſcombe*, near the mouth of the river *Glynd*, their threſholds to be laid 2 feet lower than thoſe of the ſluices abovementioned reſpectively.

In regard to the internal drains, what will be wanted further will be in the weſt level, one to join the ſluice at *Kingſtone* ſewer, which ſewer, when properly ſcoured out, will drain the weſtern parts of the level; and thoſe parts laying near the river, as far north as *Cockſhutt*, will be drained by the back drain, which will of courſe be formed, by taking the matter for embanking. In *Ranſcombe* a new drain muſt be made, or the old ones ſcoured out from the ſluice to the pool; but the back drain of the bank will be an effectual drainage for all the parts of the level near the river.

This is the whole, therefore, that can be expected to be done at a joint expence in theſe two levels; the diviſion and other drains are to be made by the reſpective proprietors, at their particular expences, and which I don't conſider as any part of the object of this report.

At the time of my view the river had but an inconſiderable fall from *Lewes Bridge* to the mouth of the river *Glynd*, ſo that when the ſhallows are removed, the water in the river, as already mentioned, will, in its ordinary ſtate, be reduced 4 feet at *Lewes Bridge* below what I found it *, and ſometimes near 5, ſo that in the *Lewes* brooks above *Cockſhutt*, the ordinary ſurface of the water in the river will be about 3 feet below the ſurface of the land; and in the brooks north of *Lewes Bridge* from 3½ to 4 feet and upwards; ſo that, taking away ſome ſhoals above bridge to facilitate the paſſage of the water, I look upon all theſe brooks as in a ſtate of drainage, liable, indeed, to be overflowed upon great downfalls of rain; but as, according to this conſtruction, theſe downfalls will ſpeedily run off, and leave the meadows dry, they will be liable to no other inconveniencies than what waterſide meadows generally are; what little banking or drainage will be further neceſſary for their ſecurity, I ſuppoſe to be left to the diſcretion and management of each particular proprietor.

The ſame reaſoning will hold with reſpect to the brooks upon the *Glynd*, eaſt of *Ranſcombe*, for the water being reduced from the ſurface, I found it full 5 feet perpendicular at the out-fall of the *Glynd* into *Ouſe*, there will be little further to do, than to ſcour out the river *Glynd*, ſo as to take advantage of the falls ſo obtained; the ſcouring out of the river *Glynd* I look upon as a work particular to the brooks eaſt of *Swale*

* The water under *Lewes Bridge*, when the levels were taken, was 3 feet 8¼ inches below the top of the aiſler courſes of the S. E. wing of the bridge.

Bank; and what further banking and draining may be neceſſary, I in like manner ſuppoſe to be the work of the reſpective proprietors, and not the object of this ſcheme, which is to point out the general methods by which the whole will be put in a *capacity* of drainage, not to drain the lands, ready for the huſbandman.

I have already ſhewn that the work of the drainage thus conſtituted will be advantageous to the navigation of the river for the barges, and an advantage for which, in my opinion, they ought to pay a toll towards the eaſe of the general undertaking: it now remains to ſhew that the conſtructions propoſed will be no ways detrimental to the harbour of *Newhaven*; on the contrary, I propoſe to demonſtrate, that it will be a conſiderable advantage, upon the principles of the firſt ſcheme now deſcribed, for as to the ſecond it cannot be made a queſtion.

I know it will be immediately apprehended, that the tides being ſtopped at *Piddinghoe*, will occaſion a leſs influx of the tide at the mouth of the harbour; and as a leſs influx will produce a leſs reflux, the power will thereby be diminiſhed, by which the ſand, ſhingle, &c. is driven out to ſea, that is brought into the harbour's mouth by ſtorms and hard gales of wind bearing ſtrong upon the coaſt; but this reaſoning, however plauſible it may appear, and however true it may be in ſome caſes, yet in the preſent it will not hold; but I muſt obſerve, that if admitted, the quantity in queſtion is ſo ſmall in proportion to the whole, that its effects can produce no ſenſible difference in the ſcour of the harbour; the quantity of tide water then in queſtion will be only ſuch as flows into and out of the river above *Piddinghoe* ſhallow; this, at the time I was there, amounted to a riſe and fall of 5 feet, as already ſtated at *Piddinghoe* ſheep-waſh, but at *White Wall*, not $2\frac{1}{2}$ miles up the river, the riſe and fall were not above a foot, and at *Lewes Bridge* ſcarcely ſenſible, ſo that the greateſt part of the influent water was contained in about $2\frac{1}{2}$ miles of river, at the mean depth of 3 feet, and at a mean width not exceeding 30 or 35 feet *, which will evidently bear but a ſmall proportion to the water contained in the river from the pier of *Newhaven* to *Piddinghoe*, where the mean riſe and fall was three times as great, the mean breadth more than double, nearer three times, and the length above three miles, beſides the water flowing a conſiderable breadth near a mile up the old harbour, as far as the tide mill: this would be the proportion, ſuppoſing all the tide's water above *Piddinghoe* to be quite loſt; but the real quantity of reflux loſt by the river above *Piddinghoe* will be greatly diminiſhed, below what is

* I am ſenſible that in dry ſeaſons, when there is leſs land water in the river, the riſe and fall of the tides will be greater, and be ſenſible further up the country; but as the efflux will be leſs for want of the land water, the effect in ſcouring muſt be leſs than at the time above ſtated.

above

above ſtated, when it is known that the tide at *Piddinghoe* did not riſe ſo high by above a foot (I made it 1 foot 3 inches) as it did at the pier head the ſame tide; from whence it follows that the tide having room to ſpread and ſpend itſelf faſter than it can be ſupplied at the mouth, the ponds within are never filled within 6 or 7 inches at a medium ſo high as they would be if they were ſo much leſs, as to have time to fill to the level of the tide at ſea: we have therefore grounds to ſay, that if the tide was prevented from ſpending itſelf ſo far up the river, it would occaſion the remaining ſpace to fill to a higher level, and thereby take in a quantity upon the whole nearly as large as if ſuffered to flow further; and that this reaſoning is true, further appears from this fact, that in ſpring tides the water gets ſo far up the river, that not having tide to get back again, the ſame tide fills the river above *White Wall* fuller and fuller, which is not evacuated but by the neaps that ſucceed *.

From what has been ſaid we may be aſſured, that the ſtop of the tides at *Piddinghoe* could be of no great conſequence to the harbour, even upon a ſuppoſition that the tide water there lodged *is uſeful* towards clearing the harbour's mouth, which I come now to ſhew that it is not, but in the preſent caſe detrimental.

When the wind is *in ſhore*, and brings an heavy ſea upon the harbour's mouth, the ſhingle is thereby put in agitation; and if a ſtrong tide of flood happens during ſuch violent agitation, the indraught of the tide brings in a quantity of ſhingle, and loads the entry of the harbour, and this effect will (*cæteris paribus*) be greateſt when the indraught is ſtrongeſt, that is, when there is the greateſt tides, and the leaſt freſh water in the river to oppoſe them; and this indraught will alſo be ſtrongeſt, when there is a narrow entry, and a great ſpace wherein the water may expand itſelf; for there the tides of flood will ſet in through the harbour's mouth the moſt rapidly. Theſe circumſtances concur in a ſtrong degree in the preſent caſe, and therefore a diminution of their *expanſion* muſt diminiſh the *rapidity of tide of flood*; at ſuch a time when the river has no great currency downwards, the tides, as already obſerved, inſtead of returning wholly to ſea, are ſpending themſelves up the river to *Lewes*, which occaſions a rapid influx, and a languid efflux; the river is therefore at this time in no condition to evacuate the ſhingle ſo brought in; here it muſt lie till ſomething happens to turn the balance the contrary way, and this is done by the land floods joining with the tides, which promote a briſk reflow to ſea. Now at ſuch times, the land floods will at *Piddinghoe over-ride* the tides, and the ſluice doors will be open the whole time of tide; the ſluice therefore will not in any reſpect impede the land floods from getting to ſea, and by the embanking

* N. B. The high water before referred to was near 1 foot higher at *Piddinghoe* than it was at *Lewes Bridge*.

of

of the river, they will be brought down with greater rapidity, and thereby produce a ſcour ſuperior to what it can obtain in the preſent ſtate of things. Since therefore the rapidity of the tide of flood will be diminiſhed, and the ebb tide increaſed, at ſuch times when alone they can be of uſe in ſcouring, the effect upon the clearing of the harbour's mouth muſt be beneficial *.

I come now to deſcribe the ſecond method of drainage, whereby the river will be left in its natural courſe; and whereby, if the drainage of the weſt level and *Ranſcombe* were the only objects in view, the work would be done at the eaſieſt expence, as will be more particularly ſeen by the eſtimates.

This conſiſts of an entire embankment of the rivers againſt all extremes of floods, ſo far as the drainage is carried, thereby ſhutting the river entirely out; ſo that inſtead of diſcharging the down-fall waters into the river at the point oppoſite the reſpective tracts of ground, it is to be collected into one drain, and finally diſcharged into the open tide's way by means of a ſluice, which, ſhutting out the tides, prevents at once the reverſion of the water for the whole level. This ſluice and drain will be far leſs in point of water-way than that before propoſed, having nothing to convey to ſea but the down-fall water of the levels to be drained; whereas the other muſt be large enough to afford a ſufficient paſſage to ſea to the flood waters of the whole river in the greateſt extremes of floods. This ſecond method is in many caſes to be preferred, as it ſtands clear of all difficulties reſpecting the altering the current or navigation of the river, and is in itſelf *moſt perfect*; but in the preſent caſe the north and eaſt levels are ſituated ſo diſadvantageouſly, with reſpect to their communication with the general out-fall, that to accompliſh the whole in this way will be more expenſive than by the firſt method. But to proceed:

I propoſe the out-fall ſluice to be nearly at the ſame place of the river as before propoſed, and to be of 12 feet water-way; from hence a drain of 12 feet bottom to be carried through *Tarring Tenantry*, and by means of a ſubterraneous tunnel, to croſs the river *Ouſe* in a proper point between *Stock Ferry* and *Stockhouſe*, from thence through the low grounds of *South Eaſe*, and croſs the *White Wall* to a point of diviſion in *Rodmill Tenantry*, there to branch off in three directions; the N. W. branch to fall in with *Kingſton* drain; the north branch to paſs between the two *Ries* to bring down the cock-ſhot water, which will be uſeful for the cattle, and prevent its being particularly embanked; from thence through *Lewes* brooks below bridge, and under the river *Ouſe* in a ſubterraneous tunnel, anſwerable to one of the old paſſages that croſs the ſtreet eaſt of *Lewes*

* By fixing doors proper for that intent, this ſluice may be made uſeful for procuring artificial ſcours at low water in dry ſeaſons.

Bridge

Bridge; from thence through the *Malling* brooks, and again crossing the river into *Lewes* brooks above bridge, from thence upland port brooks, skirting the river with a bank and drain (without following the minute windings) as far as the drainage is wanted to be carried, which, on the west side, I have supposed to be as far up as the iron-hole; for the sake of the brooks east of the river another tunnel will be necessary to convey their drainage across the *Ouse* a little above Mr. KEMP's, and thence skirting the river with bank and drain as on the east side, as far as the artificial drainages are wanted, which I have supposed to be the *Carp-Hole or Horse-shoe* brook.

Returning now to the point of division, the N. E. branch is intended to cross the river *Ouse* by a subterraneous tunnel, and proceed directly to the pool in *Ranscombe*, from thence proceeding eastward to cross the boundary of *Ranscombe*, and after that skirting the river *Glynde* with a bank and drain on the north side till we are past the turnpike-road, and the brooks grow broad and open on the south side the river; from this point the drain is to be pursued on the north side, supposed to *Edley*, for draining the great hoof, &c. crossing the *Glynde* from the said point, by a subterraneous tunnel, and in like manner carrying a bank and drain on the south side; this will serve for a drainage of the *Firle* brooks, and what else on that side of the river may be further necessary.

The *Beddingham*, *Asom*, and *Itford* brooks are also to be drained by a subterraneous tunnel under the river *Glynde*, to communicate its drainage with *Ranscombe*.

The carrying the drainage through the *South Ease* and *Tarring* brooks may possibly be objected to, as bringing the waters upon them; but as they lay higher than the rest, and the earth dug out of the drains forming, of course, a much more than sufficient barrier bank, they cannot possibly receive any prejudice, but, on the contrary, will have their drainage rendered more effectual by draining into the new cuts proposed to pass through them.

J. SMEATON.

Austhorpe, 27th July, 1768.

P. S.

P. S. The general level, as taken the 18th and 19th of June, 1767, from the sea to *Lewes Bridge*, the latter being the moon's quarter-day, was as follows:

	Ft.	In.
Rise from the sea (at a flowing water) to the pier head at *Newhaven*, - - -	4	$0\frac{1}{2}$
From the pier head to *Sleeper's Pool*, - - - - - - -	1	$8\frac{1}{4}$
From *Sleeper's Pool* to the top of the *Broad Salts*, below *Piddinghoe*, by estimation, - -	0	10
From low water surface, at the top of the *Broad Salts*, to the water's surface in the west level near *Shine* sluice, - - - - - - -	6	5
Rise from the surface of the west level water to the surface of ditto, at *Lewes Bridge*, by estimation, - - - - - - - -	0	4
	13	4

N. B. On comparing the high water mark at the pier head at *Newhaven* on the 17th, with the foregoing levels it appears, that the high water at the pier head was above the level of the surface of the water at *Lewes Bridge* the same day 2 feet 2 inches.

ESTIMATE for *Lewes Laughton* Level, upon the principles of the first scheme.

GENERAL WORKS.

	£.	s.	d.
To a sea-sluice of 40 feet water-way, containing three passages, two of 13 feet each, with pointing doors to seaward to keep out the tides, and ditto to the land, for holding up water for the navigation in dry seasons, and one passage of 14 feet, to be furnished with a double pair of gates pointing to seaward, in order not only to keep out the tides, but to form a navigable lock to let the vessels pass at all times; to be built with brick, with stone quoins and facings, the thresholds to be laid 2 feet below low water mark, in that part of the river opposite the sluice, - - - - - - - - -	4000	0	0
To cutting a new river opposite *Piddinghoe*, to be 27 feet bottom, and sloped in proportion of 3 to 5, (that is 3 perpendicular to 5 horizontally) and being $9\frac{1}{2}$ feet deep, will be 59 feet at top, and which, for 4 furlongs 3 chains length, will contain 42,948 yards, at 5*d.* including drainage, - - - - - - - - - -	894	15	0
To $7\frac{68}{100}$ acres of land for the cut and cover, the cover being supposed at half value, is reckoned at half quantity; the value per acre I do not pretend to judge of, but if, for the sake of estimation, it be reckoned at 40*l.* an acre, this will come to, - -	307	4	0
To a new cut from the turn of the river below *White Wall*, to the turn of the rirer above *Stock Ferry*, being of the same dimensions as the other, and 4,6 furlongs in length, will, at the same price, come to - - - - - - -	957	3	9
To $8\frac{22}{100}$ acres of land, at the same price, cut and cover, - - - -	328	16	0
In order to prevent the necessity of letting in the tides, for the sake of the navigation in dry seasons, and also to give the water a more free passage in its lowest state, it will be necessary to deepen the following shoals, viz. *Dean* shallow, *Sound* shallow, *Bramble Bush* ditto, *Snow* ditto, *Cliff* ditto, and *Tapsall* ditto, these at 100*l.* each, will come to -	600	0	0
General works, - -	7087	18	9

Parti-

Particular Works for the Levels west of the *Ouse*, below *Lewes-Bridge*, and on both sides above, on north of ditto.

	£.	s.	d.
To making new banks on the west side of the river, from the head of the new cut below *White Wall*, to the high land at *Southover*, being in length 28 furlongs, to be at a medium 24 feet seat, 6 feet top, and 6 feet high, the matter being taken out on one side, so as to form a back drain, at 3*d*. - - - - - - -	770	0	0
To land to be converted into a drain, in order to make the bank, (the land being low, I reckon no spoil of land by the cover of the bank,) this, for 28 furlongs length, will be 10,1 acres, which, if valued at 15*l*. per acre, will come to - - -	151	10	0
To making a new sluice of 6 feet clear water-way on the north side of *White Wall*, the threshold to be laid two feet lower than *Skine* sluice, to be built of brick, with stone facings, - - - - - - - - - -	300	0	0
To making a drain from the new sluice to join *Kingston* sewer, to have a 6 feet bottom, slopes as 3 to 4, and, at a medium, 5 feet deep, this, for 7$\frac{1}{2}$ furlongs, at 2$\frac{1}{2}$*d*. per yard, including drainage, is - - - - - - - -	120	6	3
To land to be cut for the said drain, the land being low, I reckon no damage for cover 2$\frac{7}{10}$ acres, which if reckoned at 15*l*. per acre, - - - - -	33	0	0
To taking out four shallows above *Lewes*, that obstruct the regular course of the current, viz. the washing-place opposite *St. John's*, *Bell Shallow*, above Mr. KEMP's, *Stoneham* sheep-wash, and *Hansey Flats*, at 50*l*. each, - - - - - -	200	0	0
Particular expence of the west and north levels, - - -	1574	16	3

Particular Works for *Ranscombe* Level, and Level on the *Glynde*, on the east of the *Ouse*.

	£.	s.	d.
To embanking *Ranscombe*, from the high lands at *Walker's Hole*, 10 furlongs, and up the river *Glynde* to *Swale Bank*, 9 furlongs, of the same dimensions and price as before, -	522	10	0
To 6$\frac{84}{100}$ acres of land, to be converted into a drain to make the bank, at 15*l*. -	102	12	0
To a new sluice at *Ranscombe* of 4 feet clear water-way, the threshold to be laid 2 feet lower than the threshold of the present sluice, to be built as the former, - - -	200	0	0
To embanking of *Ranscombe* as before proposed, supposes the matter to be taken at the greatest convenience all round, but for the more perfect drainage of the brooks upon the *Glynde*, above *Swale Bank*, it will be necessary to take out a part of the earth from the river *Glynde*, in order to dyke it out; *the extra expence*, therefore, in dyking out the river *Glynde*, from its mouth to *Swale Bank*, and therewith in part making the bank alongside, so as to make it 1 foot deeper than the present threshold of *Ranscombe* sluice, may be set at	90	0	0
To dyking out and scouring the river *Glynde*, from *Swale Bank* to the west end of the *Great Hoof*, for procuring a general out-fall to the eastern brooks, being in length 12 furlongs, that is 480 roods, at 10*s*. - - - - - - -	240	0	0
Particular works for *Ranscombe*, and levels on the *Glynde*, - - -	1155	2	0

ABSTRACT

ABSTRACT.

	£.	s.	d.
General Works, - - - - - - - - -	7087	18	9
Particular expence of the weſt and north levels, - - - - - -	1574	16	3
Particular works for *Ranſcombe*, and levels upon the *Glynde*, - - - -	1155	2	0
	9817	17	0
Upon the above we may allow 10 per Cent. for unforeſeen accidents, and contingent works not brought to account in the above, together with utenſils and ſuperviſal, - -	981	15	8
	10,799	12	8

SECOND ESTIMATE for *Lewes Laughton* Level, upon the principles of the ſecond ſcheme.

GENERAL WORKS.

	£.	s.	d.
To the ſea ſluice at the tail of the main drain of 12 feet clear water-way, the threſhold to be laid 1 foot below low water mark, with pointing doors to ſeaward, and draw gates to land-ward, for holding up water in dry ſeaſons for the uſe of cattle, to be built with brick, with ſtone facings, - - - - - -	1200	0	0
To the main drain, to be carried as per plan, through *Tarring Tenantry* to *White Wall*, to have a 12 feet bottom, ſlopes as 3 to 4, to be dug as deep as the ſill of the ſluice, that is at a medium $8\frac{1}{2}$ feet deep, the length being 15 furlongs, at $4\frac{1}{2}$*d.* per yard, including drainage, - - - - - - -	1361	5	0
To putting a ſubterraneous tunnel acroſs the river *Ouſe*, in the reach between *Stock Ferry* and *Stockhouſe*, of 12 feet water-way, - - - - - -	1000	0	0
To continuing the main drain from *White Wall* to the point of diviſion, bottom and ſlopes as before, the depth being about 6 feet, and $5\frac{1}{4}$ furlongs length, at 4*d.* including drainage,	268	17	7
To purchaſe of lands from the out-fall ſluice to *White Wall*, cut and damage of cover at 66 feet broad, and 15 furlongs length, will contain 15 acres, which, if eſtimated as before at 40*l.* will come to - - - - - -	600	0	0
To purchaſe of lands for the cut from *White Wall* to the point of diviſion, (the land being low, I reckon no damage of cover) at 27 feet breadth, and $5\frac{1}{2}$ furlongs length, make $2\frac{3}{10}$ acres, which, if valued at 15*l.* per acre, comes to - - -	34	5	0
General works, - - - -	4464	7	7

ESTIMATE

ESTIMATE of works to be done in the west level.

	£.	s.	d.
To continuing the drain from the point of division, up to meet *Kingston* sewer, upon a 6 feet bottom; the batters 3 to 4, and at a medium 5 feet deep; this for 2,4 furlongs, at $2\frac{1}{2}$ *d.* per yard, including drainage, comes to - - - - - -	38	10	0
To land for the drain to join *Kingston* sewer, containing $\frac{35}{100}$ acres, at 15 *l.* - -	5	5	0
To embanking the river *Ouse* from *White Wall* to the top of *Lewes* brooks below bridge, to be at a medium 24 feet seat, 6 feet top, and 6 feet high, at 3 *d.* per yard; the forming a back drain included, will, for 30 furlongs, come to - - - - -	825	0	0
To $10\frac{8}{10}$ acres of land, converted into a drain for forming the aforesaid bank, at 15 *l.* -	162	0	0
To cutting a new north sewer, from the point of division to its junction with the bank drain, to have a 6 feet bottom, batters as 3 to 4, and five feet mean depth, containing 11 furlongs in length; this at $2\frac{1}{2}$ *d.* per yard, including drainage, comes to - - -	176	9	2
To land for the above cut, no spoil of cover, containing $3\frac{22}{100}$ acres, at 15 *l.* per acre, -	48	6	0
Particular charge of the west level, - - - - -	1255	10	2

Estimate for the north Brooks above *Lewes Bridge.*

To making a 5 feet tunnel across the river, at the head of *Lewes* brooks, - -	600	0	0
To making a sewer of 6 feet bottom, with slopes as 3 to 4, and therewith forming a bank, by laying the earth on one side, at a medium 5 feet deep, will make a bank 20 feet seat, 5 feet top, and 5 feet high; this at $2\frac{1}{2}$ *d.* per yard, cutting and banking included, for 30 furlongs, from the river opposite the head of *Lewes* brooks, below bridge, to the iron hole at the head of *Hansey* farm, - - - - - - -	481	5	0
To land for the above sewer, containing $8\frac{8}{10}$ acres, at 15 *l.* an acre, no spoil allowed for banks, - - - - - - - - - - -	132	0	0
To probable extra expences in the cut passing the street east side of *Lewes Bridge*, -	250	0	0
To a 5 feet tunnel to pass the river, from *Malling* brooks to *Lewes* brooks, above bridge,	500	0	0
To a 3 feet tunnel to pass the river above Mr. KEMP's, to communicate the drainage from the east side, - - - - - - - - - -	400	0	0
To making a bank and sewer from the said tunnel on the east, to the *Horse-Shoe* brooks, of the same dimensions as the former, being 21 furlongs, - - - -	336	17	6
To land for the above drain $6\frac{15}{100}$ acres, at 15 *l.* - - - - -	92	5	0
North brooks - -	2792	7	6

Estimate for the drainage of *Ranscombe.*

To cutting a main drain, from the point of division to *Ranscombe* pool, to have a 6 feet bottom, batters as 3 to 4, and at a medium of 5 feet deep, the length being $8\frac{1}{2}$ furlongs, at $2\frac{1}{2}$ *d.* per yard, - - - - - - - - - -	136	7	1
To land for the above cut, containing $2\frac{49}{100}$ acres, at 15 *l.* - - -	37	7	0
Carried forward -	173	14	1

	£.	s.	d
Brought forward, - -	173	14	1
To making a 6 feet tunnel acrofs the river *Oufe*, - - - - -	800	0	0
To embanking *Ranfcombe*, from the high lands at *Walker's Hole*, by the river *Oufe*, to the *Glynde*, and up the river *Glynde* to *Swale Bank*, to have a 24 feet feat, 6 feet top, and 6 feet high; this for 19 furlongs, at 3 *d*. per yard, back drains included, comes to - -	522	10	0
To 6,84 acres of land, occupied by the drain from whence the bank is to be taken, at 15 *l*.	102	12	0
Particular charge for *Ranfcombe*. - - £.	1598	16	1

Charge of draining the eaft brooks, or brooks eaft of *Ranfcombe*, as alfo thofe of *Beddingham*, *Afcm*, and *Itford*.

To cutting a drain, from *Ranfcombe* pool to the eaft extremity of *Ranfcombe*, to have a 6 feet bottom, flopes as 3 to 4, and at a medium 5 feet deep; this, for 6 furlongs, at 2½ per yard, will come to - - - - - - - - -	96	5	0
To land for the above 1 $\frac{76}{100}$ acres, at 15 *l*. - - - - - - -	26	8	0
To cutting a drain of 6 feet bottom, with flopes as 3 to 4, and therewith forming a bank againft the river *Glynde*, by laying the earth on one fide, at a medium 5 feet deep, will make a bank of 20 feet feat, 5 feet top, and 5 feet high; this, for 18 furlongs from the head of *Swale Bank*, through the *Great Hoof* to *Horfe Brook*, at 2½ *d*. per yard, will come to	336	3	0
To land for the above drain 5 $\frac{27}{100}$, at 15 *l*. - - - - - -	79	0	0
To putting a 3 feet tunnel acrofs the river *Glynde* below the *Great Hoof*, in order to communicate the drainage of *Firle* brooks with the former drain on the north fide, - -	150	0	0
To embanking the *Firle* brooks againft the river *Glynde*, oppofite the *Great Hoof*, and therewith forming a drain, fuppofed of the fame dimenfions as the north-fide; this for 9 furlongs, will come to, - - - - - - - - - - - -	144	7	6
To land for ditto 2 $\frac{64}{100}$ acres, at 15 *l*. - - - - - - -	39	12	0
To putting a tunnel acrofs the river *Glynde*, in order to drain *Beddingham* brooks, of 3 feet water-way, - - - - - - - -	200	0	0
To embanking thofe brooks againft the river *Glynde*, and thereby making a drain behind the bank, which is to have a 24 feet feat, 6 feet top, and 6 feet high; this, at 3 *d*. per yard, for 7 furlongs, will come to - - - - - - -	192	10	0
To land for the above drain 2 $\frac{52}{100}$ acres, at 15 *l*. - - - - -	37	16	0
To embanking *Afcm* and *Itford* brooks, againft the river *Oufe*, and thereby making a drain behind the bank to communicate with that of *Beddingham*, being in length 14 furlongs, which being of dimenfions and price as *Beddingham*, will come to - - - -	385	0	0
To land for the above drain 5 $\frac{4}{100}$ acres, at 15 *l*. - - - - -	75	12	0
Particular charge of the brooks upon the *Glynde*, exclufive of *Ranfcombe*, - -	1762	13	6

Abftract

Abſtract of the drainage of *Lewes Laughton* Level, by the ſecond method.

	£.	s.	d.
The general works for bringing the drainage to the point of diviſion in the weſt level, -	4464	7	7
The particular charge of the works for the drainage of the weſt level, - -	1255	10	2
Eſtimate for the north brooks above *Lewes Bridge*, - - - - - -	2792	7	6
Eſtimate for the drainage of *Ranſcombe*, - - - - -	1598	16	1
Charge of draining the brooks eaſt of *Ranſcombe*, as alſo thoſe of *Beddingham*, *Aſem*, and *Itford*,	1762	13	6
Upon the above we may allow 10 per cent. for unforeſeen accidents and contingent works not brought to account in the above, together with utenſils and ſuperviſal. - -	1187	7	6
	13061	2	4

Auſthorpe, July 27, 1768.

J. Smeaton.

A SHIP's

A SHIP's PUMP.

DESCRIPTION of a Ship's Pump, designed by JOHN SMEATON, Engineer.

A Pump of this construction was designed in the year 1765 by Mr. SMEATON, and executed from his directions by Mess. HURREY and Co. at *Howden Dock*, upon the river *Tyne*, the latter end of the same year, which meeting with the approbation of the master of the ship on board which it was first fixed, who reported that it had actually saved the ship, some others have since been made nearly similar by the same company, but the superior expence has hitherto prevented so great a demand as might have been expected. In the present design, in which the whole has been carefully reconsidered, I have not rigidly adhered to the particularities of the first construction, but altered such smaller matters as convenience seemed to suggest.

Besides the advantages that were expected to accrue above the common form from better mechanism and proportion of the parts, the following was in view: the common ship's pump in general delivers its water upon the main deck, which, according to the largeness and construction of the ship, is 4, 5, and 6 feet above the load water line, at the same time that the load water line is not above from 14 to 18 feet above the ship's bottom; it therefore appears, that the ordinary pumps lift the water from $\frac{1}{3}$ to $\frac{1}{4}$ higher than the level at which the water might be delivered, and thereby require $\frac{1}{3}$ or $\frac{1}{4}$ more power to do the same work, or with the same power to do less work than they might do by $\frac{1}{3}$ or $\frac{1}{4}$, in case the water was delivered at or just above the water line for this purpose.

A A, boxes let in through the ship's side, and caulked just above the load water line.

B B are side pipes, jointed with the boxes, and with

C C, strong planks bolted against the sides of the pump, in order that the side pipes may be got out and in without disturbance to the pump.

D D is a stand-pipe, to be carried up to the main deck, or as high as is thought necessary, that when the seas rise above the orifices, or the ship in distress, should be under her load water line, that the water may not revert and run into the ship: and here

here it is to be noted, that both boxes and pipes ſhould be wholly under water, yet it will no ways interrupt the action of the pump; for whenever the water in the ſtand-pipe riſes above the level of the water without, the preſſure of the column in the ſtand-pipe will cauſe it to make its way through the ſide pipes; ſo that in this caſe no level will be loſt, and though the pump is at reſt, no water can revert down the pump, becauſe there are the valves of both bucket and fixed box to prevent it.

The preſent deſign is adapted to be worked at the height of 22 feet by four men, who working at a moderate rate, ſo as to hold it an hour, will in that time deliver 20 tons. This is upon a ſuppoſition of raiſing the water to the uſual height; but if, by the application of the maxims above deſcribed, this perpendicular is ſhortened to 16 or 17 feet, then will the ſame delivery nearly be made by three men, or proportionably more by four men, that is, as 17 : 22 :: 20 : 26 tons at 17 feet; but in this caſe, the diſtance of the center of the lever or brake muſt be lengthened from 1 foot 6 inches to 1 foot 11 inches 3, and the barrel muſt be lengthened 4 inches.

According as the deſign is drawn, viz. for a perpendicular of 22 feet by four men, they are ſuppoſed to make no more than 25 ſtrokes per minute, moving the pump-rod $13\frac{1}{4}$ up and down at each ſtroke. This will be much better than to make ſhorter ſtrokes and quicker, as they uſually do; in this caſe their hands will move up and down about 4 feet 6 inches, and the ſame number of ſtrokes, ſcope, and preſſure at the hand will be ſufficient for the reduced perpendicular, but then the ſtroke of the pump-rod will be $17\frac{1}{4}$ inches.

With reſpect to the mechaniſm, I believe it will appear ſufficiently plain by the deſigns, which are drawn true to a ſcale; but it may be neceſſary to remark, that the working-barrel is to be of braſs, and very truly bored, the bucket and fixed box of the ſame conſtruction as thoſe uſed in the ſteam-engines, and the pump-rod is to be made of the bulk repreſented in the figures, not by way of ſtrength, but by way of weight, that when the brake is liſted up the pump-rod may readily deſcend by its own weight; and it is to be noted, that if the weight ariſing from the dimenſions ſpecified does not carry it down with ſufficient readineſs, that it is a ſign the bucket is too hard leathered, or the valves too heavy.

It is to be obſerved, that the foot of the pump is to be let through the cieling betwixt two of the floor timbers, and not to touch the bottom or outſide planking within $2\frac{1}{2}$ inches, and that the lower end be rounded trumpet faſhion. I entirely object to the pump's ſtanding upon its lower extremity, with holes bored to let in the water.

N. B.

N. B. If the foot ſtands cloſe to one or both timbers, there ought to be left 3 inches between the bottom and the planking.

In caſe the pump is made to the 22 feet height the ſtand-pipe will then become unneceſſary; and therefore to allow a proper length and weight to the pump-rod it will be proper to let down the working-barrel door and box lower down in the tree. The quantity muſt be aſſigned by the convenience of coming at the door; but the working-barrel had better not be above 16 or 17 feet above the bottom, if it can be avoided.

The four men are ſuppoſed to ſtand one on each ſide the middle ſtem of the brake, and one on each outſide of the branches, and every quarter of an hour they will find an eaſement by changing hands, which is done by changing places.

This pump may be worked by ſix men, but not ſo as to produce a greater quantity in proportion to four; it may alſo by three, but then they muſt change every quarter of an hour.

It may be made alſo to work double, in which caſe eight men may be employed with advantage; but as I imagine two independent pumps will be better adapted to ſhips uſe, that if one be out of order, or happen an accident, the other may be ſerviceable, it is for this reaſon I have not given a deſign for a double pump.

I ſuppoſe it ſcarce needful to ſay, that it would proper that a bit of the cieling ſhould be made to lift up near the pump's foot, that a man may occaſionally get in his arm to clear away any chips, ſand, dirt or other matter that may happen to be drawn thither.

Auſthorpe, 9th Auguſt, 1768. J. SMEATON.

CARRON FURNACE.

The REPORT of JOHN SMEATON, Engineer, concerning the Improvements of the Blaſt at the furnace at *Carron*, No. 4.

HAVING maturely conſidered the eaſieſt and moſt effectual way of altering the blaſt No. 4, ſo as to perform its buſineſs equally with No. 1, I recommend the following alterations, yet, without a total change, which is not the preſent object, the company will be obliged to ſubmit to its uſing more water than No. 1, though, in this reſpect, they will find it greatly improved beyond its preſent ſtate.

I would adviſe that the water-wheel and the three cylinders, with their reſpective beams, remain as they now do, as alſo the frame that holds the crank, but to add a fourth cylinder abreaſt of the other three, on the outſide or furtheſt off from the water-wheel, as alſo a fourth beam abreaſt of the other; the fourth cylinder to be of the ſame ſize, and in all reſpects fitted up ſimilar to the other three. On this occaſion it will be neceſſary to caſt a new crank with four necks, making right angles with one another, and at diſtances anſwerable to the four beams, and having the ſame ſweep as at preſent. I am not perfectly clear whether there may be room enough between the preſent outmoſt cylinder and the wall to place the new one, but if not, the wall muſt be cut away to make room for it; with reſpect to the beam, it is no matter if it works very near the wall. Another couple or frame muſt be added for the crank like the preſent, and like the preſent the fourth neck may work in the air without an outward ſupport. The receiver or air veſſel will probably want recaſting, to receive a fourth air-pipe from the fourth cylinder, unleſs the workmen can contrive to cut a hole into it, and by proper ſtraps to confine the additional pipe thereto.

As I obſerved a great deal of friction in the rods paſſing the collars in the top of the cylinder, and yet loſt a great deal of air, I mentioned laſt ſummer a method of leathering them, as well as thoſe of the fire-engine, in a different way, whereby they would not only be rendered air-tight, but the friction in a great meaſure avoided; and, that this method may be properly and ſucceſsfully applied, I incloſe a drawing, which method I adviſe to be applied not, only to the new cylinder but to the three old ones, which may be done by cutting off the preſent necks, and drilling holes for the bolts.

DECRIP-

DESCRIPTION of the Collar of Leather to be applied to the Blowing-machine at *Carron*, No. 4.

A B repreſents a portion of the cylindrical rods that work though the collar of leather.

C D is a portion of the ſection of the great plate that covers the top of the cylinders.

E F is a ſection of a cylindrical piece of wood, having a cylindrical hole through the middle, through which the rod may ſlide freely, but with as little ſhake as poſſible, which is to be made of beech, crab-tree, yew, or ſome hard or tough wood that will wear well with iron.

a b c a b c ſhews the ſection of the leather by which the hole is made air-tight, and is like an hat with the top of the crown cut out.

G H I K G H I K is a ſection of a cylindrical box for holding the cylindrical piece of wood, with proper flanches, by which the box is ſcrewed down to the cover C D, and by which the plate, of which L M is the ſection, is ſcrewed down ſo as to hold faſt.

N O is the ſection of a piece of leather for ſecuring the joint betwixt the box and the cover.

It is obvious from the figure, that no part of the cylindrical rod is intended to touch the ironwork nor the leather N O, but that it is to be kept ſteady by the wooden cylinder, and the joint rendered air-tight by the pliable cylinder of leather *b c b c*, which, as well as the wood, are to be changed whenever they are found to fail.

The method of making thoſe leathers is as follows:

P Q repreſents the ſection of a cylindrical iron ring, whoſe external diameter is equal to that of the wood C D, and whoſe internal diameter is about $\frac{1}{4}$ of an inch larger than the diameter of the cylindrical iron rod A B.

R S is the ſection of a flat round piece of leather of about $\frac{1}{8}$ of an inch thick, being of the thickeſt ſort of leather uſed for the upper leathers of ſhoes.

T V W X

T V W X is a piece of hard wood, turned to the ſhape here repreſented, whereof the part T is of the ſame diameter as the cylindrical rod A B and V W, to the ſame diameter as the wood E F; then having cut the piece of leather to about an inch more in diameter than V W, with a mallet ſticking upon the head of the piece of wood at X, the leather will be forced into the iron ring, and form the ſhape of an hat, and with a knife cutting off the ſuperfluities even with the outſide of the wood V W, it will then be of a ſize proper for uſe; after ſtaying ſome little time, releaſe it, and with a ſharp narrow-bladed knife cut out the crown even with the inſide of the cylindrical part of the leather, and by holding the blade of the knife parallel with the axis of the cylinder, it will give it the ſhape *a b c a b c*.

The leather will be rendered more compliable, if need be, by being firſt wet, and will keep its ſhape better if ſuffered to dry in a thin hoop, whoſe inſide is the ſame as the inſide of the ring P Q; if it cannot be made without puckering, it is a ſign that the part T is too prominent, for even ½ an inch of turn down will anſwer the purpoſe, dintle leather wetted is alſo more compliable than the common tanned.

It is to be obſerved, that the rods be drawfiled very ſmooth, and firſt of all worked with a mixture of ſoft greaſe and powder of black lead, and afterwards black lead ſimply.

It will alſo be of further advantage, in reſpect to the ſaving of water, to lay the water about three buckets higher upon the wheel, according to the method firſt propoſed for No. 1.

J. SMEATON.

Auſthorpe, February 11, 1769.

Anſwer to Queries by Meſſ. GRIEVE and BENSON.

Carron, July 10, 1769.

Mr. GASCOIGNE having ſhewn me Mr. SMEATON's letter to-day, in which there is the following query, viz.

" Mr. GRIEVE informed me, that at the rate I ſaw No. 4 a-going, viz. 18 cylinders per minute, that ſhe did 30 baſkets per day: query, what is her common rate of blow-

ing, that is, how many cylinders in common with a full head, and how many baſkets is then done?"

To which I anſwer, that 18 cylinders per minute is the uſual rate of blowing at No. 4; that ſhe blows down from 30 to 35 charges per day; ſhe is not now allowed to go more than 18 cylinders a minute, which is performed at the lower gate at all times, and with the upper gate when the pool is very full. Some time ago both gates were uſed, even then ſhe never went more than 21 or 22 cylinders per minute, nor more than between 30 and 35 charges per day, yet I have known her drive as many as 45 charges per day; ſuch is the uncertainty of founding on the number of charges as the baſis of a calculation.

He alſo informed me, that No. 3 made 15 cylinders per minute with 1 gate, and 18 cylinders with both; query, how many baſkets reſpectively?

To this I reply, that No. 3, with a full head, does make theſe cylinders; at this furnace we always blow with both gates, and therefore I cannot ſay how many charges ſhe may run at 15 cylinders per minute; but at 18 ſhe blows down from 25 to 29 charges per day, and if the water in the pool be 2 feet or 30 inches lower than full head, this No. 3 furnace will not drive above 15 or 16 charges per day.

Mr. Smeaton will pleaſe to advert, that a charge conſiſts of ſeveral baſkets of mine, coal, and lime-ſtone, which is put into the furnace when the materials are ſunk in her to a certain depth; now this charge conſiſts ſometimes of more or leſs baſkets than at other times, juſt as the working of the furnace requires it; and it muſt likewiſe be obſerved, that the quality of the materials has great influence on the driving of the furnace.

John Grieve.

When No. 1 blows 25 cylinders per minute, ſhe will make 28 baſkets per day.

When No. 2 blows 34 bellows per minute, ſhe will make 20 baſkets per day.

J. Benson.

Mr.

Mr. BENSON's Anſwers to Mr. SMEATON's Queries of the 11th, as far they reſpect No. 1 and 2.

Carron, July 12, 1769.

IN the firſt place Mr. SMEATON will pleaſe to obſerve, that the coals and lime-ſtones, uſed in each furnace are all of the ſame qualities, and nearly the ſame quantities; the difference is not worth notice.

Query 1ſt. Anſwer. The mines uſed in No. 1 and 4 are quite different qualities, ſo can only ſay what difference there is in the weights of the mine uſed to a charge; No. 1 charge of mine is about $\frac{1}{10}$ to $\frac{1}{12}$ heavier than No. 4; when No. 1 is running 28, and No. 4, 30 to 35 charges per day, ſuppoſing both furnaces of the ſame ſhape, but they are not, No. 1 blaſt is more repelled than No. 4.

Query 2d. Anſwer. The materials of No. 1 and 2 are much the ſame; the mine of No. 1 charge weighs about $\frac{1}{12}$ heavier than No. 2; this difference ariſes chiefly from the ſhapes of the furnaces, and not from the blaſt.

Query 3d. Anſwer. The quality of the iron in No. 1 may be as good when ſhe runs 28 charges per day, as when ſhe runs 18 and 23, provided ſhe be working what we call clean natural mines, or mines not poſſeſſed of poiſonous matters; but the quality of the iron depends upon that, and the quantity of mine uſed to a charge.

Query 4th. Anſwer. I never wrought No. 2 at 10 to 12 charges per day; but was that the caſe, ſhe would take a double ſet of men to work her, and the iron would be ſo cold for want of its mother cinder, which cinder can only be produced in a blaſt furnace by a proper quantity of blaſt, it would be of no ſervice but for pigs, and ſcarcely would run out of the hearth even into them.

JOHN BENSON.

Mr. GRIEVE's Anſwers to Mr. SMEATON's ſix Queries, dated the 11th inſtant, as far as they reſpect No. 3 and 4. B. Furnaces.

Carron, July 12, 1769.

TO Query 1ſt. The coal and limeſtone uſed to a charge is much the ſame in all the furnaces.

 No. 1

No 1. carries commonly $\frac{1}{12}$ or $\frac{1}{13}$ part of more mine to a charge than No. 4. but it must be observed that the quality of the mines used at No. 1. and No. 4. are always different, and to come at the ability of each, they should be loaded with equal materials.

To Query 2d. I reckon No. 3 carries $\frac{1}{12}$ or $\frac{1}{17}$ part more mine than No. 4; but this is as uncertain as the answer to query 1st, on account they are never loaded with the same sort of mine.

To Query 5th. With the same materials, I believe, No. 1 and No. 4 will make nearly the same quality of iron, yet there may be a difference in favour of No. 1, on account of her drier situation, and her better make.

To Query 6th. This depends entirely upon the nature of the materials; No. 3, when she drives 25 to 29 charges a day, will make as good iron as when she drives only 15 or 16 charges a day, provided, in both cases, she be working what we call wholesome mines; but if the materials are endued with any pernicious qualities, every furnace will make better iron by working than fast: The reason is obvious, by driving slow the materials remain longer in the body of the furnace, and so have more time to throw out their sulphurs, or the heterogeneous matter, with which they abound, escapes by sublimation or attraction, which hard driving would carry down with and poison the iron.

JOHN GRIEVE.

EXPLANATION for the Design of the Blast Machine for the Furnace No. 2, at *Carron*.

AS in this machine I have the advantage of ordering the water wheel, which I judge best to be over-shot, this circumstance reduces its height so much, that, by a small enlargement of the cylinders, it can be allowed to go at such a speed as to do without geer, which however well they have answered in No. 1, where they were necessary, yet where the same proportions in the movements can be accomplished without geer, are more properly avoided.

I have also chose, instead of making two regulator beams working a cylinder at each end, as in No. 1, to make four beams or great levers with cylinders at one end only, by this means, the strain of the crank always laying downwards, and bearing upon its

brasses

braffes the fame way as the water-wheel, will work more eafy and pleafant, and be lefs liable to get a fhake, and be out of order by continuance of wear: The whole, therefore, of the motions being performed with more eafe and fimplicity than No. 1, I expect it to be fubject to lefs attention and repairs, and that it will not require above $\frac{4}{5}$ of the water to work it, taken by No. 1.

There will be more timber in the framing, but as it will be nothing but common fir timber, I apprehend this will be no object, and this will be more than faved in the water-wheel and axis, the fpurn-wheel, and pinion.

No. 1 is a defign for the upright of the water-wheel; it is here fhewn to be of 20 feet diameter, but as, on my laft view at *Carron*, I underftand that the wheel No. 2 lays lower than the reft, and is fometimes affected by tail water, when *Stenboufe* mill-dam is full, a circumftance I was not before apprifed of; in order to avoid that, it may, perhaps, be neceffary to reduce the diameter of the new wheel from 20 feet to 19 feet 6 inches; but, yet, if *Stenboufe* mill-dam never throws above 3 inches dead water upon the bottom of the prefent wheel, then the new wheel may be laid as low as the prefent wheel, becaufe that quantity of dead water, fuppofing the tail water-courfe from the wheel be open and free, will be of no prejudice to the going of the new wheel.

The reduction of the water-wheel to 19 feet 6 inches is, again, only upon a fuppofition that the pond is fubject to be reduced 1 foot 9 inches below head, as I faw it the 7th inftant; but if it is never fuffered to go above 1 foot below head, as advifed in my report of this day, or, at moft, 14 or 15 inches, then the water-wheel may be of its full fize, though it fhould be obliged to be raifed at the bottom from 3 to 6 inches, to fufficiently clear the tail water.

The elevation here given is fuppofed to be of the outward front, but as I find the tail water goes off the contrary way to what is here fhewn, and will require a different kind of penftock, for which I will fend a particular defign when I return to *England*, it will be proper to lay a fweep to the breaft of this wheel, to fit it as clofe as poffible, but it may either embrace the wheel a quarter round, or only $\frac{1}{8}$ of the circle as is found moft convenient in the execution; the two different ways are fhewn according to the letters A B C and A D E.

The width of the wheel is fuppofed to be as great as the conduit will allow, as it will work fteady like No. 1, no allowance need be made for fhake.

No.

No. 2 is a plan of the whole machine, and an elevation of one of the truſs frames and beams, with a ſection of one of the cylinders; upon which it is only neceſſary to obſerve, that as the method of framing the truſs-frames are the ſame as No. 1, whatever difference there is in the diſpoſition, will be ſufficiently obvious from the draught.

It is, however, to be obſerved, that as, for the eaſe of caſting, I have ſuppoſed the crank to be caſt in two pieces, particular notice is taken that one of the heads be ſet a ſmall matter atwiſt, with the arms of the crank, that when the whole crank comes to a bearing in the box that couples them together, the arms of the firſt half of the crank may make a perfect right angle with the arms of the ſecond, otherwiſe if this circumſtance is not attended to, the clearance neceſſary to get the box entered upon the two heads, will produce a ſhake, that when the whole comes to a bearing, the arms of the two halves of the crank will not ſtand ſquare to each other, which will produce an inequality in the blaſt.

The crank end of the regulator beam or lever has a piece of caſt iron A, which is to be made of ſuch a weight as to overhaul the piſton, which, for the ſake of lightneſs in this machine, is to be made of wood, or as light of iron as it can be properly caſt; the piſtons, however, are to be leathered, as in No. 1; the propoſed uſe of the weight at A overhauling the piſton, is to prevent the crank-rod from changing its bearings upon the crank neck, for, by always bearing downwards, it will be no matter whether the neck-collars be tight or not, ſo that the only collars that will be needed to be kept tight, (which they very eaſily may, having but little motion,) are the tops of the crank and piſton rods, and the center gudgeon of the levers.

B is a proviſionary flanch, which is here ſhewn to be mute; the opening to be about 6 inches diameter in the clear, and the uſe is, that in caſe a perfect equality in the blaſt ſhould be afterwards found to be preferable to all others, as I am at preſent much inclined to ſuppoſe, from hence there may be made a communication to an air receiver or veſſel, which will fully effect that purpoſe.

J. SMEATON.

Kerſe Houſe, July 31, 1769.

The

The WATER at CARRON.

The REPORT of JOHN SMEATON, Engineer, concerning the quantity and difpofition of the water at *Carron*, from a view taken thereof the 7th of July, 1769.

AS the feveral blaft furnaces at *Carron* are of different dimenfions, work upon different kinds of ore, and take different quantities thereof at a charge, the wheels take their water at different heights, and, at the time of this view, the pond from which they were fupplied was fo low, that the head of water upon each wheel was a good deal uncertain in the different penftocks; it is not to be expected that any very accurate conclufion can be drawn by way of comparifon of the feveral machines, in regard to their powers of reducing the ores or mine into metal; yet, in attempting the comparifon in the beft way I am able, it appears to me that feveral matters offer themfelves which feem worthy of ferious attention from the Company.

Amidft the uncertainties above mentioned, it feems impoffible to fix upon any abfolute criterion or common meafure to which they can all be reduced. The quantity of metal produced from the furnace feems improper, becaufe the pooreft ore (I muft prefume) takes moft labour of the furnace, and yields the leaft iron; the different quantity of air that each machine throws into its refpective furnace appears alfo equally unfit, becaufe, if we are to judge by this alone, it will appear that the machine No. 4 will, with an equal fupply of water, throw out more air in a minute than No. 1; and this will alfo hold with No. 3, and therefore we muft conclude that the machine No. 1 is inferior to No. 4, and alfo to No. 3. A conclufion which I fuppofe muft be rejected from all experience hitherto had, and confequently the premifes from which it is drawn.

It remains therefore that the number of charges, as they do not much differ in weight, which each furnace can work off in a given time, relative to a given quantity of water, is the only handle we can at prefent lay hold of, and is, as I perceive, the fame by which the managers and workmen reckon; and though, on the account before mentioned, it may not be very exact as common meafure, yet I find the differences of the effects of the furnaces relative to a given quantity of water are fo very remarkable, that though our conclufion formed from thence will be fhort of perfect accuracy, yet they may enable us to adopt a better diftribution of the water than at prefent.

The

The diſtribution and effects of the water on the day of view was as follows:

	Strokes per minute.	Charges per day.	Cube feet of water expended per minute.
Table 1. No. 1.	19	23	267
2.	28	18	555
4.	$16\frac{1}{2}$	30	780
Total charges per day		71 with	1602 cube feet of water per minute.

N. B. At this time No. 3 was ſtanding ſtill.

When all the furnaces have a full head and ſupply of water, the number of ſtrokes of the cylinders and bellows per minute, relative to the number of charges per day, as per information of Meſſrs. Benson and Grieve, are in the following table; and comparing the ſeveral heads of water and apertures that theſe muſt obtain with the preſent, the expence of water relative to thoſe ſtrokes and charges will alſo be as therein ſpecified.

	Strokes per minute.	Charges per day.	Cube feet of water.
Table 2. No. 1.	25	28	481
2.	34	20	761
3.	18	27	1362
4.	18	$32\frac{1}{2}$	852
		$107\frac{1}{2}$	3456

Now, comparing the reſpective numbers in the ſecond table with thoſe of the firſt, it appears, that the quantity of water expended to drive an increaſed number of charges, greatly exceeds the proportion in which the number of charges increaſe; for taking the totals, to advance the charges from 71 to $107\frac{1}{2}$, that is nearly as 2 to 3, the water muſt be increaſed from 1602 to 3456, that is more than in the proportion of 2 to 4. Again, in the furnace No. 1, to advance the charges from 23 to 28, the water muſt be almoſt doubled, and the diſproportion greater or leſs is obſervable in all the reſt. Mr. Grieve reports, that reſpecting the furnace No. 3, with the upper gate drawn alone, with a full head of water, it will give 15 cylinders per minute, but with both gates drawn, in which caſe the expenditure of water will be doubled, the number of cylinders are no more than 18; and as it otherwiſe appears that the quantity of charges relative to each furnace is almoſt, but not quite, proportionable to the number of cylinders, in the furnace alſo the diſproportion between the water and the charges is as great as in any of the reſt, and indeed the proportion, though in ſomewhat different degrees, appears from the united teſtimony of the machines of every conſtruction.

Obſerving

Obſerving this diſproportion, and my mind ſuggeſting to me the uſe that might be made thereof, towards a better allotment of the water, I found it neceſſary to know whether the iron produced by the ſeveral furnaces at their low rates of working was as good as the iron produced at their higher rates of working; and from the anſwers I have received from Meſſrs. BENSON and GRIEVE, it appears that the low rates of working produces quite as good iron as the higher, and in caſes of impure mine conſiderably better; however, it ſeems there are rates of working ſo ſlow, that the iron would not be put in a ſufficient fuſion, as would happen if No. 2 was reduced from 18 to 10 or 12 charges per day.

From a diligent compariſon of the above particulars with each other, and alſo with the theory which they ought to conform to, if the experiments could have been made with accuracy, I have endeavoured to ſettle the proportions in which each furnace would work with an equal diſtribution of water, according to the quantity in which it was uſed during my obſervations on the day of trial, which, according to table 1, was at the rate of 1602 cube feet per minute, ſay 1600; by this means we ſhall be enabled in ſome meaſure to enter into the merits of each, as well as to elucidate ſome other points. Suppoſing then the 1600 feet equally divided amongſt the whole four, each will work with 400 cube feet per minute, and their ſeveral performances may be expected as follows.

Table 3.		Strokes.	Charges.	Cube feet of air per minute.
	No 1.	$23\frac{1}{4}$	27	1194
	2.	25	16	
	3.	12	18	1459
	4.	13	24	1811
	Total No. of charges		85	
	Ditto per table 1.		71	
	Difference		14 in favour of diſpoſition table 3.	

If we ſuppoſe 1600 feet of water divided equally amongſt the three furnaces of table 1, they will each have 533 cube feet per minute; they may then be expected to move as follows:

Table 4.				
	No. 1.	26	29	533 cube feet per minute.
	2.	$27\frac{1}{2}$	$17\frac{1}{2}$	
	4.	$14\frac{1}{2}$	$26\frac{1}{2}$	
	Total number of charges	73		
	Ditto per table 1ſt	71		
	Difference	2 in favour of diſpoſition table 4.		

N. B. This laſt diſpoſition, though it advances the number of charges by two, yet as it throws more work upon No. 1 and 2 collectively, and leſs upon No. 4, which works ſingle, I ſuppoſe the convenience upon the whole may be leſs.

The following equal diſpoſition of the water amongſt three furnaces may perhaps anſwer better, as it not only makes a better produce, but divides the work of the two houſes more equally.

Table 5.	No. 1.	26	29	533 cube feet per minute.
	3.	13¼	19¾	
	4.	14½	26½	
	Total charges -		75¼	
	Ditto per table 1ſt		71	
	Difference - -		4¼	in favour of diſpoſition Table 5.

From the above diſpoſition, I deduce the following probable inferences.

1ſt. That the number of charges does not depend wholly upon the quantity of air produced by the machines, but in a great degree upon the regularity of the blaſt.

2d. That the number of charges does not depend upon the velocity wherewith the air is thrown into the furnace, but rather upon the quantity of air that is made to paſs regularly through the materials contained in the furnace in a given time.

3d. That this quantity ſo made to paſs may have its limits, for too much may ſpoil the metal by over-heating it, and too little will not produce heat enough to give it, and keep it in the neceſſary ſtate of fuſion, and which limits can only be aſcertained by experience.

4th. That the worſt machine is capable of working a given number of charges with leſs expence of water than will be required to be added to the beſt, to advance its produce by an equal number.

6th. That the moſt advantageous way, when water is ſhort, is to keep down No. 2 and 3 to as few charges as can be admitted to do their buſineſs well, in point of quality, and to divide the water, after theſe are ſerved, equally betwixt No. 1 and 4; but when No. 1, ſo ſerved, runs above 28 charges, or No. 4 above 30, then ſuch overplus to be equally drawn upon 2 and 3, and ſo on, upon the waters mending, till they are all advanced to their higheſt pitch, and the contrary method upon its decline.

We

We will now examine the real ſupplies at the times of ſhorteſt water, and endeavour to aſcertain the beſt means of uſing it.

From the gage of the river's water taken at the long arch it appears, that at that time it amounted to 990 cube feet per minute; but as the water was ſaid to come down more in the day than the night, on account of ſtoppage of mills above, and alſo that ſometimes by continuance of drought runs ſtill ſhorter than at preſent, it was thought it was in the greateſt ſcarcity on an average not more than $\frac{2}{3}$ of what we then meaſured.

The fire-engine at that time went from 6 to 8 ſtrokes per minute of $5\frac{1}{2}$ feet each; but as ſhe was frequently obliged to ſtop to gather ſteam, this with other ſtoppages in the 24 hours, together with the loſs by ſhutting of valves, makes me reduce her average rate to five ſtrokes per minute at 5 feet each.

The fire-engine will therefore raiſe per minute	440
And the river *Carron* at loweſt - -	660
Total -	1100

I underſtand from Mr. Grieve that No. 3 makes good iron at 15 charges per day, and from Mr. Benson that No. 2 will not anſwer at 10 or 12; but I will ſuppoſe that No. 2 will work as well at 15 charges as No. 3 does, and as they are allowed to work well at that rate, they may be ſuppoſed to do ſo at a ſomewhat a ſmaller rate; dividing, therefore, the 1100 feet equally amongſt the four furnaces (which reduces No. 2 and 3 nearly to the rates abovementioned) we ſhall have, as follows:

Table 6.		Strokes.	Charges.	
	No. 1.	21	23.8	275 cubic feet per minute
	2.	22	14.1	
	3.	$10\frac{1}{4}$	15.9	
	4.	$11\frac{1}{2}$	21.2	
		Total charges -	75	
		Ditto per table 1ſt -	71	
		Difference - -	4 in favour of diſpoſition No. 6.	

Hence it appears that in the loweſt ſtate of the river *Carron*, by diſpoſition table 6th, there will be 4 charges per day worked by 1100 feet of water per minute more than is done by diſpoſition table 1ſt by 1600.

To compleat this view, I will ſuppoſe all the furnaces equally perfect as No. 1, and that they are confined to the ſupply of the river *Carron* alone in its loweſt ſtate, that is, 660 cube feet per minute; there will be therefore a ſupply of 165 feet for each machine. Theſe 4 machines with that ſupply will go $17\frac{1}{2}$ cylinders each, and work $19\frac{1}{2}$ charges, in the whole 78 charges per day, that is, 7 charges more without the fire-engine than they do with it at the time that the river *Carron* ſupplies 990 feet of water per minute.

In theſe computations I reject the circumſtance that No. 1 and 3 carry about $\frac{1}{12}$ more weight of ore to the furnaces at a charge than No. 2 and 4, which is much in favour of the two former; but as there appears to be ſeveral other differences of circumſtances as well as thoſe, I rather choſe to take the whole in the groſs from the number of charges, without dwelling on minute circumſtances.

Concerning the Noſe-pipes.

It is ſuggeſted in the 2d deduction, that the effect of the furnace does not depend upon the velocity wherewith the air is thrown in, but rather upon the quantity of air that is made to paſs regularly through the materials contained in the furnace in a given time.

My reaſons for this inference are the following: that in all caſes the number of charges worked by each furnace are, when proper deductions are made for the friction of the machine, very nearly proportionable to the quantity of air thrown in by the ſame machine, and though it will hold equally true, that when different quantities of air paſs through the ſame noſe-pipe, the velocity will be proportionable to the quantity, and, therefore, in like manner proportionable to the number of charges; yet, as a double quantity of air applied to a double or two furnaces with an equal velocity, produces a double effect, it is moſt probable that a double quantity of air producing a double effect in the ſame furnace, is alſo owing ſimply to the double quantity of air thrown in, the double velocity being only a concomitant circumſtance attending the throwing a double quantity through the ſame orifice; and this appears ſtill the more probable, as within certain limits a leſs velocity of air as effectually converts a proportionable quantity of mine into metal as a greater. Now ſuppoſe any furnace, for inſtance No. 1, will do her work well at 14 cylinders per minute, in which caſe ſhe is ſaid to diſpatch 18 charges with a noſe-pipe of 3 inches, if the machine is made to go 28 cylinders, and drive her air through a noſe-pipe of double area, viz. $4\frac{1}{4}$, ſhe would then blow a double quantity of air, and would only require a double quantity of water; but if ſhe is

is made to blow 28 cylinders through the ſame noſe-pipe of 3 inches, it will require *eight times* the quantity of water, and yet the number of charges *ſcarcely doubled*, and the metal itſelf, at the beſt, no better, and in ſome caſes not ſo good. Hence appears not only the great advantage in point of water, of working a greater number of furnaces at low charges, rather than a ſmaller number at higher, but alſo the advantage of applying as wide a noſe-pipe as can be admitted, ſo that the air may really enter the furnace, and not be repelled back again; and in this reſpect an equal blaſt will have very greatly the advantage over an unequal one; but I apprehend that it may be practicably known when any part of the air is repelled, becauſe when there is no ſenſible reverberation on the hand or face, it is evident it muſt enter the furnace. If, therefore, it ſhould be found, that when No. 1 goes 25 cylinders, all the air will enter the furnace from a noſe-pipe of $4\frac{1}{2}$ inches, or, for the ſake of an addition of velocity to make it enter, ſuppoſe of $3\frac{3}{4}$, it will then work with 247 cube feet of air per minute, inſtead of 481, which, per Table 2, is requiſite for the ſame number of cylinders through a 3 inch noſe-pipe; and, conſequently, if all the furnaces were equally perfect with No. 1, they would be capable, in the very loweſt ſtate of the river *Carron*, (with the preſent help of the fire-engine) of doing more work than they now do with a full ſupply of water, and without the fire-engine would do more work than they now do with it.

After all, I do not pretend to determine that things will ſucceed exactly in this manner. The phyſical nature of bodies is not to be circumſcribed by geometrical reaſonings, which have only quantity for their object; all I mean really to inveſtigate is, that if the nature and conveniencies will, *upon trial*, admit of their being worked in the manner ſuggeſted, then ſuch advantages in point of power will follow; yet I do not mean to ſay that the advantages will follow preciſely in the quantities I have ſet down; this is not to be expected, unleſs the data on which I have been obliged to proceed could have been more accurately had: however, notwithſtanding a degree of inaccuracy in the data, I preſume it cannot be ſo great but that the reaſonings thereon founded will at leaſt ſhew which way the advantage lies, and thereby furniſh matter for experiments, which, as they could eaſily be tried, and if attended with ſucceſs will be of great conſequence in the application of the preſent powers to the beſt advantage, I cannot but earneſtly recommend the trial thereof as ſpeedily as convenience will admit, which is the whole aim of what I have delivered.

Concerning

Concerning the Improvement of the Blaſt Machines.

No. 1 is now ſuppoſed compleat, and a ſtandard for the reſt.

No. 2 appears at preſent to be the moſt faulty, but when rebuilt according to the plan given in with this report, I ſuppoſe will perform at leaſt equal with No. 1 in making iron, and go with $\frac{1}{4}$ or $\frac{1}{5}$ leſs water.

No. 3 appears to take conſiderably more water than any of the cylinder machines relative to the number of charges; what preference it has in reducing thoſe charges into metal I can be no judge of. I apprehend, however, it would be conſiderably improved in its preſent form if the two blow-pipes were connected by an air-cheſt furniſhed with valves, and from thence to blow from one noſe-pipe. As this alteration may be eaſily made it ſeems worth the trial; but I apprehend it will never perform quite well till it is put into the form of either No. 1 or 2.

No. 4 will, I apprehend, perform nearly with No. 1, when furniſhed with a fourth cylinder. This I ſuppoſe, becauſe when their effects are compared when working with the ſame quantity of water as per table 3, the difference is not much greater than what ſhould ariſe from the wrong proportion of the parts of No. 4, which will be in a great meaſure corrected by the addition of a fourth cylinder.

It would be a ſaving of water in the whole if the pond of *Carron* was never ſuffered to go lower than from 6 inches to a foot below a full head, and rather than ſuffer that, to draw the neceſſary water from the reſervoir at *Larbet*, or to reduce a number of cylinders blown at each machine, according to the proportions ſuggeſted in tables 3d and 6th.

Concerning the Boring Machines.

		Cube feet.
The over-ſhot wheel in boring a gun of 6¼ inches, uſed per minute	- - -	341
The cutting-machine	- - - - - - - - -	168
	Together	509
But as one cutting-mill ſupplies two boring, ſubtract half the cutting-mill's water	- -	84
Neat quantity expended to keep a cutting and boring machine at work continually	- -	425

In

In regard to the ſmall boring and turning mill at the ſide above, I find it takes 495 cube feet per minute; but as I underſtand it only goes when there is a full head and plenty of water, I lay it out of the conſideration.

It appears then, that to keep one boring machine, with the neceſſary cutting, going continually, they take near $\frac{2}{3}$ of the whole produce of the river *Carron* in ſhort water times, that is, almoſt as much as the fire-engine draws; and though theſe machines be ſuppoſed to go only 12 hours in 24, yet they will ſtill conſume as much water as will work the furnace-machine No. 1 at 22 charges per day; a deſtruction of power which has been very properly ſeen by the Company, and therefore propoſed it as very deſirable that thoſe machines ſhould be intirely ſilenced in ſhort water times, and a new one erected in lieu thereof upon the tail water proceeding from all the furnaces collectively.

Now if theſe 2 machines require 569 cube feet per minute to work them when there is a fall of at leaſt 20 feet, a fall of 6 feet, (which is the utmoſt I think can be well had for the tail-water into the tide's way) will require 1697 feet; whereas the river *Carron* does not ſupply half of this water in very dry ſeaſons, and the engine water will not apply itſelf to this machine; notwithſtanding, I can aſſure the Company that I can undertake to furniſh a deſign, wherein the water can be applied in ſo ſuperior a manner, in point of power, to what it is to the preſent machines, that the river *Carron*, at 660 cube feet per minute, upon a fall of 6 feet only, ſhall drive thoſe machines as effectually as they are now driven with 509 feet upon their preſent head.

Kerſe-Houſe, July 31, 1769. J. SMEATON.

RESOLUTIONS of the *Carron* Company.

AT a monthly meeting of the partners of *Carron* company, held at *Carron*, 10th of Auguſt, and following Days, 1769.

Preſent, Mr. JOHN ADAMS,
Mr. CHA. GASCOYNE,
Mr. THOMAS ROEBUCK,
Mr. WM. CADELL, jun. and
Mr. JOHN CADELL.

Mr.

Mr. SMEATON's report of the 7th of July laſt, made in conſequence of our letter, dated July 1, having been read to the meeting,

Reſolved, That the ſaid report be approved of, and that the neceſſary ſteps be taken, as ſoon as convenient, to make ſuch trials and experiments of the uſe and diſtribution of the water, according to the tables contained in the ſaid report.

Reſolved, That Mr. SMEATON be requeſted to give the company a ſcheme and plan of the boring-mill mentioned in his report, as ſoon as it ſuits his conveniency.

Reſolved, That the thanks of the meeting be tranſmitted to Mr. SMEATON, as a mark of the ſenſe they entertain of the attention he is pleaſed to pay to their works.

CHA. GASCOYNE, P.

Some Remarks concerning the deſign for a double boring mill for cylinders and guns, to be erected upon the tail-water of the *Carron* works.

I propoſe the machine to be erected upon the oppoſite ſide of the tail water-courſe to that on which the blaſt furnaces ſtand, and in any part of the yard that upon the whole ſhall be thought moſt convenient, which depending upon a great number of circumſtances that I cannont be acquainted with, muſt be judged of by the Company; nor is it all material to the action of the machines whether they ſtand as cloſe to this water-courſe as they can well be diſpoſed of, or be carried further into the yard. According to the general deſign No. 1, it is propoſed to turn the tail water-courſe of theſe mills a quarter round, ſo as to proceed nearly in a parallel direction to that of the preſent courſe to *Stenhouſe* mills, and to fall into the tail water-courſe at *Stenhouſe* mills, at ſuch point as ſhall be thought moſt convenient on account of digging, ſeparation of lands, &c. but in caſe the tail water-courſe is made to fall into that of *Stenhouſe*, above the loweſt point, to which Mr. LAURIE levelled, it will be neceſſary to clear up ſo much of the old water courſe as ſhall prevent any material loſs of fall between that loweſt point and the falling in of the new water-courſe.

Mr. LAURIE makes a fall of 8 feet 5 inches from the *bottom* of the furnace tail lead, at the lower ſide of the bridge next below the boring-houſe, to the loweſt point to which he

he levelled, but as the furnace tail lead will be charged with ſome depth of water *above its bottom*, before the tails of any of the furnace wheels will be affected thereby, we may account the whole fall, from ſurface to ſurface, to be ſomewhat more than he has ſtated. In the preſent deſign I have ſuppoſed a neat deſcent at the mill of 7 feet only, for this principal reaſon, that I obſerve the ordinary ſpring tides flow within about 3 feet of the top of *Stenhouſe* mill-dam, and as the neap tides flow within 4 feet at the height of the ſpring tides, I have therefore laid the wheels ſo that they may not be interrupted daily by the tides. I propoſe, therefore, that an over-fall of 50 feet length in the crown be erected at or near the place where the preſent one now is, at *Stenhouſe* mills, to be laid 3 inches lower than the height of the water in the tail water-courſe at the works, when the wheels there are juſt free of tail-water, by which means the whole water will be vented over the over-fall, without affecting the furnace wheels, when the tail-mills are all ſhut; the height, therefore, of the water marked in the deſign for the water-wheel to be of 1 foot 3 inches above the crown of the fall, will be 1 foot 3 inches below the top of the over-fall; and allowing 2 inches for the run of the water from the works to the over-fall, this crown will be 1 foot 8 inches below the higheſt ſtate of the water in the tail water-courſe, that will not affect the furnace wheels; but in caſe all the water from the furnace can be pent over *Stenhouſe* dam without putting them in tail water, then this over-fall will be unneceſſary. The reſt of the fall to Mr. LAURIE's loweſt point of level will be 1 foot, or ſomething better, for declivity between the boring-mills and the ſaid loweſt point; but if it ſhall appear upon further examination that the wheels can be laid lower than I have ſuppoſed, without being affected by the ordinary neap tides, then I would add ſo much to the fall of the mills marked in the ſaid water-wheel deſign 5 feet 9 inches; keeping the crown of the fall at the ſame height reſpecting the furnace-wheels, or not exceeding 1 inch or 2 lower, and for which, if neceſſary, I will ſend a new curve for the fall, every thing elſe remaining the ſame. It is therefore the height of the neap tides at high water that determines me as to the fall to be taken at the boring-mills; and as this height will not be diminiſhed by any cut that may be made on the loops of the river below, that circumſtance may fairly be laid out of the queſtion, there being at preſent more deſcent to *Reay's Ford* than can be taken in for the reaſons abovementioned.

The power required for boring depends ſo much upon the circumſtances of the thing to be bored, that it is a matter that cannot be reduced to any exact calculation; but this I am not in the leaſt doubtful of, that in the very loweſt ſtate of the *Carron* water it will carry the gun-mill with two guns boring and one cutting off, which is, I apprehend, more than the three machines at preſent do, and that in all ordinary times the cylinder-mill requiring leſs power, may be worked at the ſame time. It will, however, be ne-

ceffary that the mill-gates, &c. at the *Stenhoufe* mills be kept in good repair, otherwife a quantity of water will be expended there in leakage.

The rings of the two water-wheels I have defigned to be of caft iron, in order that they may act as loaded flies, and thereby preferve the motion more fteady.

I have fuppofed all the axes to be of caft iron, with fluted heads inftead of fquares, to keep them from wearing off the corners, and are what I would recommend; but forged iron fpindles with fquare ends may be made ufe of inftead thereof, if better approved of, for reafons I don't fee. I have fhewn the fame fluted heads upon the two ends of the water-wheel axis that are next one another, by means whereof, if an extraordinary occafion fhould offer, the power of both wheels can be combined fo as to act on either fide.

I have been in fome doubt whether fo large a wheel as is reprefented for boring the large cylinders could be caft upon that plan; if not, the fame fized wheel of 78, as is reprefented on the main axis for guns, being applied on each fide, anfwers to the mean motion for cylinders; and I apprehend it may be worth while to have two motions, as the wheel will bore two cylinders at once, or a cylinder may be placing on one carriage and got ready while the other is boring: as the motions ftand in the plan they anfwer nearly to 3, 2, and 1.

If it is found convenient to have the boring-mills fo much further from the furnaces that the gangways may come towards the prefent tail-water courfe, then the quarter round turn may be made in the new lead to be cut from the fame to the new mills, fo that the tail-water of the boring-mills will go away directly without any turn. I don't mention this as preferable to the fituation in which they are fhewn in the plan, but as an hint to fhew the different fituation in cafe it fhould happen to be more fuitable to the general convenience.

N. B. A beam being fupported aloft acrofs the three gangways for the guns, with a tackle hanging from a running roller upon the beam, will take up the gun from the gun-head carriage, and put it upon either of the boring carriages. The fame may be done by a crane in the middle.

The width of the new tail-water courfe fhould be a 10 feet bottom with proper flopes, but where walled 9 feet will be fufficient.

Concerning

Concerning the alteration of the present mill for cylinders and gun-heads, if the same motions are adapted thereto as are designed for the new mills, they will equally answer. But it would go with still less water if the wheels were made so much lower as to be overshot.

In its present state it would go with far less water, and do its business better, if the motion it now has for gun-heads was adapted for cylinders, and the cylinder motion (that is, of the great axis) was applied to the gun-heads; if made new it would be right to use iron rings for the sake of the weight, whether of its present size or reduced to an overshot.

JOHN SMEATON.

Austhorpe, October 15, 1770.

EXPLANATION of the Design for building a Dam for the *Carron* Works at *Duni Pace.*

THIS design is made upon a supposition that the bed of the river where it is to be built lays about 7 feet below the level of the pen required. Mr. GASCOIGN's letter of January 16, acquaints that the bed of the river is 4 feet deeper than the top of the sill of the flood gates; supposing therefore the water over that sill at dam's height to be 3 feet, the whole height of the dam's crown above the bed of the river will be 7 feet, as drawn in this design, of which the declivity of the slope surface of the dam is intended to be 5 feet; but if the height of the dam's crown should require to be either higher or lower by 1 foot, it will make no material alteration in the design; for if it is higher than 7 feet, as it is presumed that this is reckoned from the *deepest part* of the bed of the river, there is no need to increase the declivity of the slope surface of the dam between the crown and the skirt; but if it is lower than 7 feet, the slope of the dam may be diminished so much as to leave the skirt about 2 feet above the bed of the river.

It is obvious from the design that the body of the dam is intended to be of quarry rubble; and as the greatest part of what relates to it will be readily comprehended from the design, it will be sufficient to explain those things that are less obvious.

A B, No. 1 and 2, represent two courses of flags or flat stones from 2 feet to 3 feet square, or oblong, as they can be got, and of 4 or 5 inches thickness: those flags are proposed to form the grand stop or pen of the water: if the whole bed of the river at the place where these rows of flags are to be footed can be come at, so as to get them inserted about 1 foot below the bed of the river, it will be sufficient without any piles for footing the same upon; but if this should prove otherwise, it will be proper to drive a row of grooved sheet piling, as represented at C C, No. 1, supported by a string piece D, and that supported and trenailed down upon the bearing piles D E; this piling to be carried on at least across such deep part where a proper footing for the flags cannot be come at, and the terminations secured with the projecting part of the flags so as to make nearly a water tight joint: but was it not on account of expence it would be still more eligible if this row of piling was carried quite across, and inserted into the dam's end walls.

At any rate, the first thing to be done, is to lay in so much rubble as will support the sloping flags, and fill up the downstream side of the sheet piling, so as to break the fall of the water over them, at the height of the ground line D F; while this is doing, it will be proper to go on with the sheet of plank piling at the tail of the dam G G, supported in like manner by the string piece H, and that by the bearing piles H L, and the whole is covered by a 2 inch fir plank to preserve the parts above-mentioned from the wear of the water, and which may be renewed when worn out in a course of years, without disturbing any thing upon which the solidity of the structure depends. This sheet of plank piling in all grounds that are not rocks, is indispensible; but as the use of them is not to stop the water, but to keep in the sand and other matter, if the expence of grooving the plank piles is thought material, and the ground is sufficiently uniform to admit their being drove close edge to edge, without grooving, then this part of the business may be dispensed with: by the time the tail sheet piling is compleated, the whole area betwixt C and G should be got filled with rubble, and the row of stones marked I, which are supposed to stand edgeways to the rest, are to be got into their places: in this situation the dam will be entirely safe from derangements by floods, which will go over the work without hurting it. As the work advances, the flag stones A B are to be got in gradually, the apron of earth upwards of the flags, and the rubble and upstream setting as shewn in the section.

It is to be noted that the two rows of flags are intended to break joint one upon the other, and to be scappelled so as to lay or to pack together tolerably true; the joints all the way up are to be well stuffed with fog or *live moss*, and to be bedded with the same between the two rows of flags, this will prevent the earth from being forced through the joints

joints by the preſſure of the water, and will render the whole perfectly water tight if properly attended to; the earth itſelf being guarded by the rubble and ſetting above it.

While the dam is raiſing, there is no doubt but that the ſpeats going over it will ſcoop out the ground below the tail ſheeting, ſo as to become 2 or 3 feet deeper than the natural bed of the river; when this happens the whole muſt be filled up with whin ſtones, or, what is beſt, large whin ſtones ſplit into three or four pieces by powder, which will enable the angular fragments to ſtick together better then the whole round ſtones; and if any derangement happens here by ſpeats, which is the likelieſt place to happen, it muſt be attended to, and ſupplied till the water makes its exit from the tail ſheeting by a regular declining current.

I think it not only unneceſſary, but impracticable, to give directions about the building of the dam's end walls, as I cannot determine the ſituation of the body of the dam reſpecting the land on each ſide from any thing that is before me, and the method of returning the ends of the walls into the land, ſhewn for the dam at *Larbet*, will be ſufficient guidance here; I have only to remark, that it will be proper to make thoſe walls, for ſome ſpace on each ſide of the crown of the dam, higher than any flood is known to riſe, and that the back of theſe wa[illegible]here the ground is diſturbed or new made, muſt be well covered or even *ſet* with [illegible]ry rubble, in caſe the flood water is liable to get behind them from the adjacent haughs; for want of this precaution, I have in more inſtances than one known the river to make itſelf a new courſe round the outward end of the dam.

It will alſo be proper to make the crown of the dam about 3 inches higher at the ends than the middle, and eſpecially towards that end where the water is diſpoſed to act the ſtrongeſt, when th[illegible]own does not make a line right acroſs the river, which is not always proper.

Table

Table shewing the expenditure of water, &c. in the furnaces at *Carron*, inclosed in Mr. Smeaton's letter to *Carron* Company of the 23d of July, 1776, in answer to theirs of the 14th ditto.

Number of the furnace.	Tons per Day expended by each furnace.	Cube feet of air protruded per minute.	Velocity of the protruded air in miles per minute.	Proportional effect produced.	Power required in proportion to the effect produced by No. 2.	Excess of power used more than in proportion to No. 2.
					Tons per day.	Tons per day.
1	11774	1288.7	8.838	100.672	10964	810
2	15760	1673.7	9.298	144.711	15760	
3	17630	1344.2	8.117	88.575	9647	7983
4	24972	1301.5	8.926	89.585	9757	15215
	70136				46128	24008

DIRECTIONS and Observations concerning the clay-mill, to be built upon the tail-water at *Carron*.

THE water-wheel, its conduits, and gate, to be in all respects the same as those of the boring-mill, except that the rings need not be of iron, observing, that in order to preserve the same head of water over the crown of the fall, that the whole be laid a few inches lower, in order to allow for the run of the water from the yard of the works to the place of the clay-mill.

I suppose the rollers themselves to be nearly the same as those now used, and to be cast upon wrought iron spindles or gudgeons: the principal difference here proposed, besides that of a very different proportion between the turns of the water-wheel and the rolls, is the addition of a fly to each roll, a larger to the driving roll, and a less to the roll driven; those are intended to keep the motion more uniform and steady, and so as not to affect the geer that drives them by the little inequalities in the passage of the clay.

These rolls are intended to go about 50 turns per minute, which, as it is considerably quicker than the present, it would greatly tend to make the work go perfectly smooth and pleasant, if they were but 18 inches instead of 2 feet length, and yet they by their greater velocity will dispatch more work.

The

The work is ſo placed that if ſtampers are deſired, they may be applied for beating the clay, ſo as to prepare it for the rolls; but if the grinding it to a fine tough paſte would be of uſe, for this purpoſe nothing would equal the runners on the edge, ſuch as are uſed for oil and gunpowder mills: this would perform the whole operation from firſt to laſt, but would not reduce the clay to the conſiſtence that the rolls do, ſo ſpeedily as the rolls. A work of this kind might afterwards, if found occaſion, be added to the other end of the axis, or in its preſent form it is capable of having a boring apparatus, or even a forge hammer applied to it if thought proper; for this reaſon, I would adviſe to make the building roomy, (of which I ſuppoſe the water-wheel to ſtand croſsways in the center) or to leave room on each ſide for building. I apprehend the wheel will ſtand beſt croſsways upon the preſent lead or leet, ſo that the building will range along-ſide thereof. In this caſe, the tail-water muſt be turned with a quarter round, the more gentle the better, but if need be, may be turned almoſt in its own breadth.

This water-wheel will drive two ſets of rollers at once, at each end, or other equivalent works, and for one pair of rolls will go with ſo little water, that I believe you will ſcarcely find the corn-mill the worſe.

J. SMEATON.

Auſthorpe, Feb. 21, 1777.

The REPORT of JOHN SMEATON, Engineer, concerning the quantity, regulation, and diſtribution of the water for working the Blaſt Machine for the four furnaces at *Carron* in dry ſeaſons, together with the improvements that may be made therein, ſo far as regards the power of water to be employed.

IN order to anſwer the above purpoſes, I ſhall not only found myſelf upon the obſervations I made myſelf upon my view thereof in October 1776, but alſo upon ſuch deductions as may be made from a thorough reviſal of all the obſervations I have formerly made, or that have been communicated to me, of the ſtate of theſe machines, by the Company at different periods; and the ſeveral computations thereon having in general been performed when I was from home, and thereby not having the opportunity of recourſe to my former papers, they have been drawn up in different terms, and with different views of the ſubject; and alſo obſerving, in the courſe of my laſt view, ſome particularities which could not be ſo noticed when the meaſures were ſent me, which would materially affect the calculation of the quantity of water expended, I have in the following table corrected the ſame, and reduced the whole to the ſame ſtandard.

Table

Table shewing a comparative view, of the several Blast machines as used at *Carron*, at different periods, from the year 1769 to the year 1776 inclusive.

	No.	Diameter of nose-pipe.	Number of cylinders.	Cube feet of air per minute.	Velocity of air per second.	Tons of water expended per 24 hours.
1769, working with short water,	1	3	19	1066	$361\frac{1}{2}$	10680
- - - - -	4	$2\frac{5}{8}$	15.3	1820	[illegible]	31200
			Sum	2886	$1164\frac{1}{2}$	41880
			Mean	1443	582	
Ditto, with full blast, -	1	3	25	1403	$475\frac{1}{2}$	19240
- - - -	4	$2\frac{5}{8}$	18	2258	945	34080
			Sum	3661	$1420\frac{1}{2}$	53320
			Mean	1830	710	
1773, February, with full blast,	1	$2\frac{1}{2}$	20	1122	547	
- - - -	2	$2\frac{3}{8}$	18	1255	557	
- - - -	3	$2\frac{1}{4}$	$17\frac{1}{2}$	1237	747	
- - - -	4	$2\frac{1}{2}$	10	1183	577	
			Sum	4797	2428	
			Mean	1199	607	
1776, July, with full blast, -	1	$2\frac{1}{4}$	23	1289	778	15245
- - - -	2	$2\frac{1}{4}$	24	1674	818	15506
- - - -	3	$2\frac{7}{16}$	19	1343	691	18210
- - - -	4	$2\frac{1}{4}$	11	1302	785	25669
			Sum	5608	3072	74630
			Mean	1402	768	
Ditto, on view in October, with full blast, - -	1	$2\frac{1}{4}$	28	1571	947	16502
- - - -	2	$2\frac{1}{2}$	$24\frac{1}{2}$	1708	835	16047
- - - -	3	$2\frac{7}{16}$	19	1343	691	15732
- - - -	4	$2\frac{1}{4}$	$12\frac{1}{3}$	1459	881	17769
			Sum	6081	3354	66050
			Mean	1520	838	

From the above table it will evidently appear, that the machines, when worked with a full blast, have taken less and less water, ever since the first view in 1769. It also appears, that the quantity and velocity of the air does not observe any regular proportion to the quantity of water expended: but it appears in general that the less quantity of air is discharged from any given machine, and the less its velocity, and the less water it will take to work it; this also is obvious from what occurs every day, that more water produces more blast in the same machine, and the contrary.

A state of the works in February, 1773, I received from the Company, with this observation: "From our present experience of the matter, the number of strokes per "minute, quoted in the annexed table, throws the air into each furnace with a degree "of velocity sufficient to keep the hearths open, and to work each machine with due "steadiness and regularity." Now from hence it appears, in particular, (see the preceding table, 1773,) that the quantity of air discharged, as well as the velocity wherewith it was projected, was remarkably near the same in all the four machines, the mean quantity being 11'99 cube feet per minute, and the mean velocity 607 feet per second, on supposition (as in all the rest) of its being discharged with an equal velocity; and as, at this season of the year, I can apprehend no scarcity of water, I must suppose the furnace then working with full blast and effect: and, as I am furthermore told, in the Company's letter of the 2d of March, that "for some years past we have fallen into "the method of making the iron at the blast furnaces into pigs proper for remelting "in the reverberatory furnace, for the purpose of working up our gun-heads and runners, which practice requires less velocity of blast than when we cast the guns immediately from the blast furnaces, and also admits of more regularity in the whole process; so that perhaps we can now manage with less water than it was thought we could "have done in 1769 or 1773." I, say, these things considered, we may ground ourselves here, that if 1200 cube feet of air is thrown into each furnace per minute, and with a velocity of from 5 to 600 feet per second, we shall certainly have sufficient blast to keep all regularly going in times of scarcity of water. I am therein also informed, that many experiments having been made in consequence of my report of 1769, "from "all which we can clearly collect, that a nose-pipe for our purpose should not be less "than $2\frac{1}{4}$ inches, nor more than $2\frac{1}{2}$ inches." Suppose then that the nose-pipe to be settled at a mean between them, viz. $2\frac{3}{8}$, is is not to be doubted but a little less water upon the wheel when the furnace is new, and a little more when it is worn wider, will equally answer the end as a variation of the nose-pipe, as has been remarked by the workmen as necessary: 1200 cube feet of air per minute driven through this nose-pipe will produce a velocity of 532 feet per second; and that this will be fully sufficient to keep all regularly going, though perhaps not producing the greatest quantity of metal, is evident.

dent from the state of the furnace No. 1 in 1769 and 1773. The nose-pipe being now proposed the same in all, viz $2\frac{5}{8}$, 1200 cube feet of air will be discharged per minute when the different machines go respectively as follows:

No. 1, $21\frac{19}{100}$ cylinders.
No. 2, $17\frac{22}{100}$
No. 3, $16\frac{97}{100}$
No. 3, $10\frac{14}{100}$

But as fractions may be inconvenient to the workmen, I will suppose that in short water times the several machines are regulated to the number of cylinders, as in the following table; and then the quantity of water that may be expected to be expended, proportionable to what I found in October, 1776, is contained in the four last columns of the following table:

A Table shewing the expence of water according to the regulation proposed for short water seasons, and according to different states of improvement of the machines.

No.	Cylinders per minute.	Cube feet of air per minute.	Velocity of air per second.	Tons of water expended per day, as per Oct. 1776.	Expence of water No. 3 and 4 improved.	Expence of water of all improved to a 23 feet fall.	Expence of water of all improved to a 24 feet fall.
1	22	1234	547	12966	12966	12312	11800
2	18	1255	556	11789	11789	10251	9824
3	17	1202	533	14076	12240	12240	11730
4	11	1301	577	15852	12312	12312	11800
				54683	49307	47115	45154
1	2	3	4	5	6	7	8

By the first table it appears, that the blast machines, as they were working in October, 1776, were consuming at the rate of 66,000 tons per 24 hours; but by the disposition and distribution according to this last table, without any correction or alteration of the machines themselves, that quantity would be reduced to about 54,700 tons; and as it appears that the principal defects of No. 3 and 4 arise from their not taking their water so high upon their respective wheels as No. 1 does, in case these two were altered so as that the top of their upper gates should be 23 feet above the bottom of their respective wheels, then the four furnaces may be expected to work with the quantity exhibited in the 6th column, viz. about 49,300 tons per day.

If all the four furnaces were furnished with upper gates, and No. 2 wheel made larger, so as all to take the water at the same height, viz. 23 feet above their bottoms, then they may be expected to work according to column 7, that is, 47,100 tons per day; and if they were all made to take the water 24 feet above their bottoms, then they would work as per column 8, that is, with 45,200 tons per day.

As No. 3 is proposed to have an high gate, and the wheel of No. 4 to be rebuilt, and as I suppose both will be done this summer during the season of scarcity, it appears that no other provision will be wanted for the approaching season than per column 6, that is, 49,300 tons per day, because, if one of the furnaces is laid off in order to be reformed, there will be a full sufficiency of water for the other three; for it is ascertained that the river *Carron* in its lowest state affords 660 cube feet per minute, amounting to 26,400 tons per day, so that a supply of 22,900 tons per day is the utmost that can be wanted to keep all going; and this quantity can be raised by the fire-engine in its present state at the average rate of $6\frac{1}{2}$ strokes per minute, which as she may very well perform, it seems adviseable not to embarrass the progress of the other business by rebuilding of the engine this season, but to give her a good overhaul to render her performance secure *.

It will now be proper to enquire what is to be expected from the home reservoirs, made and making, towards supplying the 22,900 tons per day, above stated as the deficiency of *Carron* in dry seasons; and I suppose the dam-head of *Larbett* is to be advanced one foot higher, and all the banks raised in proportion, so as to pen the water in the furnace pool and bog reservoir to 27 feet above the bottom of the furnace-wheels; these reservoirs are stated altogether at 36 *Scots* acres; and as each *Scots* acre upon 1 foot in depth contains 1521 tons, the 36 acres will contain 54,756 tons, and upon 3 feet depth (supposing the same surface at a medium) will be contained 164,268 tons, which, divided by 22,900, gives $7\frac{17}{100}$ days.

Now when 3 feet is drawn off from 27 feet, there will remain 24 feet, which will reduce the head upon the gates at 23 feet to 1 foot, and as this is as low an head as the water can properly act upon the wheels, it will then be time to open the lower gates to draw off the remainder. As the water will there act to a considerable disadvantage, it will be ineligible to use the engine, but when the furnace-wheels take their water from their upper gates; whatever, therefore, is drawn out of the furnace-pool below the 24 feet, must be replaced again before the engine-water can produce the proper effect upon the wheel;

* By the way, the greatest defect of the present engine is the not having a sufficiency of steam; and for this reason, the speediest remedy would be to cast and set up a new 10 feet boiler in the manner of those at Cronstadt, which may be placed so as to serve the new engine when erected without a removal.

and

and as this will create a pause or stop of the whole, it will therefore be proper that it be as short as possible; for this reason it would be proper to have a stop-sluice upon the lead in the narrow part east of Mr. Lowk's house, to shut down when the surface is reduced to 24 feet, so that the *Carron* may constantly pay its tribute by cascading over the said stop, and then the furnace pool only, properly speaking, with the bog reservoir, will be emptied together below the 24 feet. Now suppose that from hence 2 feet more is drawn, which will nearly empty the bog reservoir, if the wheels take this water at 21 feet above the bottom, then they will expend by these lower gates, to produce the same effect as before, at the rate of 55,200 tons per day, from which deducting 26,400, the supply of *Carron*, there will want 28,800 from the reservoirs. I must here observe, that the quantity that we can in reality draw off, will be only from the bog reservoir, for what is drawn from the furnace-pool, will be again supplied from some recource above the 24 feet, in order to fill it to the level of 24 feet in common with the lead and *Larbett* dam, because what is reserved in the dam of *Duni Pace*, or elsewhere, in order to fill it, might, if not so wanted, have been discharged at the upper gates*. Two feet then upon 24 acres is 73,000 tons, which divided by 28,800 gives $2\frac{53}{100}$ days, and this, with $7\frac{17}{100}$ from the first 3 feet over all, makes in the whole $9\frac{7}{10}$ days water, a treasury very essential to prevent frequent stoppages, and those of short duration, but no ways adequate to the purpose of going through a long drought, which generally happens once in a summer.

We will now see how the account will stand, on supposition that the high gates are all fixed at 24 feet above the bottom of the furnace-wheels, instead of 23 feet before supposed, all the rest remaining as before stated. Now as only 2 feet can be drawn off from the whole 36 acres, they will contain 109,512 tons; and on supposition that the effect is greater from a fall of 24 feet than upon a fall of 23 feet, in the proportion 24 to 23, then the quantity of water before specified to be wanted at the high gates, viz. 49,300 tons, will be less by $\frac{1}{24}$ part, viz. 47,200, from which taking 26,400, the supply of *Carron*, there will remain 20,800 to be supplied from the reservoirs; and then 109,512 tons, the content of the uppermost 2 feet, divided by 20,800, gives $5\frac{26}{100}$ days. Again, we shall now have 24 acres upon 3 feet deep, that is, 109,512 tons in the content, and the lower gates being supposed fixed at 21 feet as before, we shall have the same divisor, viz. 28,800, which gives us $3\frac{80}{100}$ days, and which added to the former make $9\frac{6}{100}$ days; hence it appears, that this latter proportion of 24 feet height of top gates does not make so much of the reservoirs as of the former 23 feet height; but this regards only the

* The communication-stop between the bog reservoir and furnace pool before such filling must shut in, so that when the furnace pool is filled, the bog reservoir may remain empty.

bog

home reservoirs, whereas all water treasured up above the level of these reservoirs will doubtless have an effect in proportion to the fall from the gate.

This enquiry, however, leads us once more to see how very inefficacious reservoirs are likely to be when applied to a long-continued drought; and there is nothing so likely to prove a sheet-anchor as a plain, simple, well-constructed, powerful fire-engine, which when it does nothing will consume nothing, and being plain and strong, will be always in condition to work when needed, and the several parts to be easily inspected, so as to see whether they are or are not in working order.

From the above comparison of fixing the height of the highest gates at 23 or 24 feet, they are so nearly alike that the difference may well give way to convenience; and in this respect, unless that steps have already been taken in the works of *Carron* to the contrary, it would seem to me that the convenience would be in favour of the 23 feet; for, in the first place, it is indifferent to the engine, because she will draw at 23 feet so much water more than at 24 as the wheels will want to use. 2dly. Having been informed that the working of the forges is become so material an object, that it will be even worth while to assist them with engine-water, it will follow that it will be worth while to assist them with what will be equivalent to it.

Now on a former occasion I have laid it down, that a properly constructed engine of a 70 inch cylinder will, at 26 feet high, raise 56,000 tons per day; and supposing all the four furnaces reformed and regulated, so as to use according to column 7 of the last table, viz. 47,100 tons per day, *Carron* furnishing 26,400, there will be only wanted 20,700 tons of engine-water to them, the remainder 35,300 tons to be thrown into the forge-pool: now if the upper gates are fixed at 23 feet, they at once take off as much water from the reservoirs as will keep the furnaces going above seven days, whereas the whole of the remainder will only keep them going about 2½ days more; and if engine-water is to be raised for the forges, why not let off the 2 feet remaining in the bog reservoir into the furnace pools, and begin to work the engine 2½ days sooner; for this will serve instead of so much engine water to the forges, and then all perplexities will be avoided with respect to the use of different gates, as well as all attentions necessary to keep a quantity of water to refill the furnace-pool up to a level to work the upper gates, and also the necessity of a stop upon the lead avoided, as well as every attention to the use of it, so that the whole will be reduced to this simple point, that whenever the upper reservoirs are exhausted, and the lower ones reduced to 24 feet above the bottom of the wheels, then the engine begins to work, and continues till the water mends.

One

One thing however must be very carefully attended to during the working of the engine, and that is, as it only circulates the water, without increasing its real quantity, that care must be taken when the engine is working not to allow the boring-mills more water than is coming down into the furnace pool from *Carron*; and at the same time, during the working of the engine, that all the water drawn by the engine, and delivered into the pools, be regularly discharged by the furnace and forge wheels, *together with the supply of Carron*; for if less is let down than the engine draws, it will not only deprive the boring-mills of *Carron*'s supply, (which in those cases is *the whole they can be allowed:)* but *Stenhouse* dam being reduced, the engine will want water to draw; again, if more water is let down than is drawn by the engine, and *Carron*'s supply together, then the surplus quantity, after *Stenhouse* dam is full, will either run over the dam, or be spent at the boring-mills; but either way the water will be lost to the furnace-pools, which will thereby be reduced without a possibility of raising them, otherwise then by stopping the boring-mills, and letting down no more water than what the engine will draw, and then the pools will rise by the continual influx of *Carron*. These matters, so very necessary to be regulated, will, I apprehend, be done by strictly observing the following rules, a proper person being appointed to see to the observance of them.

When the furnace-pools are reduced to 24 feet, let the boring-mills be stopped, either altogether, or at nights, but so long, and at such intervals, as to suffer no water to go over *Stenhouse* dam, drawing at the same time as much water at the furnaces and forges as will supply the engine; by this treatment, the furnace-pools will gradually rise to 25 feet by the continual influx of *Carron*, which in this case they should not exceed.

When you find it exceeding that height, allow a little more water to the forges, and before it begins to run over *Stenhouse* dam, let the boring-mills draw so much as to keep it under, but not materially reduce it; by this means the boring-mills can never have more than *Carron* affords, nor the engine less than its proper quantity, nor yet the forges more than the surplusage *.

The only present difficulty is *Stenhouse* dam being leaky, and thereby letting a considerable part of *Carron*'s supply escape, that should work the boring mills; but having a lighter or punt upon the dam, if fine earth is scattered over the whole surface of the slope, for 30 or 40 yards above the dam, or so far up till you come at the natural bot-

* Perhaps the best husbandry of all, of the reservoir water, instead of throwing the lowest 2 feet of the bog water immediately into the furnace-pools, will be to let it out gradually there into in such quantity, as being expended at the forges, it will, together with *Carron*'s supply, fully work the boring-mills.

tom,]

tom, and this being ſtirred and puddled with cow-rakes, by ſome pains of this kind of three or four men for a couple of days, I doubt not but that it may be rendered ſufficiently tight for the exigencies of the preſent year; but if you think not, if you will be preparing a quantity of ſtone and piling, ſuch as was directed to be uſed at *Dunipace*, I will ſettle the particular plan for it immediately at my return from the *Derwentwater* ſpring receipt, which I apprehend will be about the middle of May.

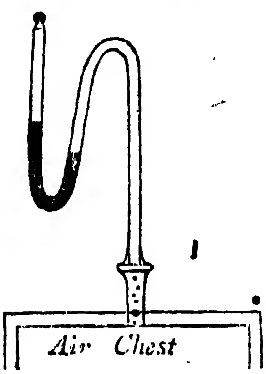
The moſt preſſing thing for this year's ſervice is to make the alterations at No. 3, and new wheel conformable to the above, 23 feet high, for No. 4; but if made 24 feet, as formerly propoſed, then all the upper gates muſt be made conformable, and it will be adviſeable to have low gates about 3 feet below the other.

When No. 3 ſtands ſtill, it will be worth while to get out and rebore the cylinder that is taper, as a conſiderable loſs of power appears to be there; and when No. 2 is ſtopped, it will be proper to reſtore the original conveyance pipes, as not only the ſtraightneſs of the pipes of 7 inches, ſince ſupplied, but the driving the air through a box, when it is unconfined, to a particular direction, is, as I have experienced, a conſiderable loſs of power. The beſt thing that can be done with No. 2 wheel, will be to clear it of the preſent buckets and ſhrouds, to mortice the rings for 16 ſtuds in each, and upon thoſe apply new rings, which, on account of being ſupported in 16 points inſtead of 8, need not be above half the ſcantling of the others; then cloathing theſe new rings with new ſhrouds and buckets, it may be made the ſame ſize as No. 4, the axis and crank being raiſed on chocks, and the crank rods ſhortened, leaving all the reſt, inſide the houſe, ſtanding as at preſent. The water penſtock muſt alſo be raiſed, but if made 24 feet high, ſhould have a lower gate like the reſt, and then it muſt be bucketed the contrary way, and have a penſtock of a different kind to throw the water back, in which however near 6 inches of perpendicular will be loſt; ſo that to draw down the pool to 24 feet, leaving 1 foot head upon the penſtock, (the over-ſhot wheels to go the reverſe way) cannot be more than $23\frac{1}{2}$ feet high.

In regulating the noſe-pipes, I would adviſe their being brought to a clear regular ſurface inſide, to ſome diſtance back from their very noſe; and if thoſe that are too ſmall are bored to the gage of $2\frac{1}{4}$ inches, ſo as to leave the noſe-part a cylinder, I have experienced it in water to throw out a more clean and leſs ſcattered column. An attention to this, and alſo to keep the tuires as narrow as poſſible, ſo as juſt to receive the column and no more, I am convinced of it, will be found very beneficial in regard to the ſaving of power, or rather to make the very moſt of the power ſtipulated.

The

The beft practical way of keeping the machines to the number of cylinders fpecified in the latter table, will be to furnifh each furnace-keeper with a minute glafs, fuch as are ufed by the fhipping for the log ; they muft, however, be ordered on purpofe to be an *exact minute*, becaufe thofe made for fea are generally fome feconds fhort, for reafons given by mariners. I have now a couple by me, which I got made in *Wapping*, for experiments, in a better manner than common, inftead of fand, being furnifhed with granulated lead, and are very exact: but after all, unlefs the leathering of the piftons could always be kept equally tight, an equal number of cylinders will not always give an equal quantity of blaft; but if when the leathers are in their beft ftate, the furnaces were furnifhed with a gage, confifting of a glafs tube, fixed with cement to a bored brafs ftopple, as per margin, with a little quick-filver, this applied to a hole in any part of the air-cheft, or general conveyance pipe, by obferving the height that the quick-filver rifes in one leg above the other, as much water applied to the wheel as will raife the gage to the difference experienced, when all was tight, will not only in all ftates of the leathers reduce the machine to the fame degree of blaft, but difcover when the leathers are defective, becaufe then it will require more cylinders to keep the fame difference of gage. Thefe gages need only to be applied occafionally, when any deficiency is apprehended, and 1 or 2 may ferve the 4 furnaces. If the top of the tube, which is properly to be open, has a bit of porous cane by way of peg, it will not only prevent the quickfilver fcattering out, but prevent its vibrating fo much by the inequality of the blaft.



J. Smeaton.

Aufthorpe, April 6, 1777.

P. S. I don't find I have given an anfwer to that letter which tranfmitted to me a fketch for the new furnace No. 5 for my approbation, being upon the conftruction of No. 2, only the water-wheel placed between the four cylinders, that is, a pair on each fide, to which, if you find it more convenient in point of fituation, I fee no objection, or, if otherwife, no preference. It would be better with refpect to the neceffary fpeed of the water-wheel, if the cylinders were not quite fo large as No. 2, viz. about 4 feet 3 inches ; but as I apprehend you have already a fet of models for the bottoms and air-chefts ready made, by which No. 2 were caft, it will anfwer nearly the fame end if you fomewhat fhorten the ftroke, that is, not to exceed 4 feet. The wheel fhould be over-fhot, and the fame height as No. 4 is to be made, and No. 2 to be raifed ; but by all means let the air-cheft be continued to join crofs the feparation of the two fets of ma-

chinery, and the blaſt-pipe go out from the middle in the moſt direct manner to the tuire, and to taper from the ſize originally propoſed for No. 2, from the air-cheſt to the noſe-pipe.

In conſidering further upon the propoſition contained in the note annexed to page 8, it appears ſtill more advantageous, if you were to keep part of the water in *Dunipace* reſervoir to apply in the ſame manner; for by this means the boring-mills need never be ſhort of water, nor yet any reſervoir water miſapplied on ſuppoſition of the forges being ſupplied with engine-water, or what is equivalent, and by reſerving thus a ſufficient part of the reſervoir water, it will even anſwer to the leakage of *Stenhouſe* dam, ſuppoſe you cannot get it tight in the way I have mentioned.

Keſwick, April 10, 1777. J. SMEATON.

DESCRIPTION of the Apparatus for putting in motion, and diſcharging any of the particular motions for boring the Gaſconades at *Carron*.

Fig. 1. The dotted ſquare *a b c d* repreſents the ſquare end of the axis of the water wheel, or any of the ſide motions driven by toothed wheels therefrom as uſual, and whether this is a plain ſquare or citadel head, is here immaterial. To this ſquare end is firmly attached an arm A B, which ſpreading both ways C D, and applying itſelf to the angle of the ſquare, this, by means of a ſimilar piece E F G, and a couple of bolts, the arm is brought on perfectly firm and ſolid, and will therefore continually revolve with the axis. At A is a mortoiſe through the arm 3 inches broad, and about $1\frac{1}{4}$ wide, capable of admitting a piece of iron faced with ſteel, and hardened, ſhaped ſomewhat like a blunt plane iron, but $\frac{5}{8}$ inch thickneſs, ſo as to fill up exactly half the mortoiſe, and conſequently its working or ſteel face will be in the direction of the radius; the other half of the mortoiſe is occupied by iron wedges for fixing it: upon this arm may be ſuppoſed to be imboſſed, but in reality caſt along with it in the ſame piece a projecting part B *e f g h* before the plane C D, and alſo before E F G, being attached to the former, but detached from the latter, which projecting piece terminates forward in the ring *i k l m*, which forms a ſocket H, alſo cocentrical with the axis, and firmly connected therewith, which being fully underſtood, the reſt will be eaſily comprehended.

Fig. 2.

Fig. 2. The ſquare *a b c d* repreſents the ſquare of a detached axis; the dotted circle *e f* repreſents the ſize of a gudgeon, which is adapted to the ſocket H in the former figure: C D are two projecting arms, that, with the axis and gudgeon, form a +, as will be readily underſtood from fig. 3, which repreſents a part of the plan of the detached axis, and wherein the ſame letters refer to the ſame parts as fig. 2. The center of the croſs C D is pierced lengthways, with a ſmooth hole capable of receiving an inch and ½ bolt, upon which, as a center is hung in fig. 2, the arm E F G H I K L, which in like manner contains a mortoiſe at F of equal ſize and diſtance from the center, as the former one at A, propoſed to hold in like manner a ſteeled iron tooth or kamm, like the former each made to project about an inch from their reſpective arms, and the ſteeled faces being contrary ways, they will meet one another with their flat faces; and it being ſuppoſed that the gudgeon *e f* being introduced into the ſocket H, fig. 1, that when the two kamms are engaged, the detached axis will be made to turn along with the original one whoſe ſquare is *a b c d*, but not otherwiſe; this will now be made more plain by

Fig. 4, wherein M is a part of the ſquare of the original axis, N the road, O the ſquare head ſeen upon the angle, as at *a b c d*, fig. 1, H the gudgeon of the detached axis, P the bolt hole through the arm fig. 2 and +, Q the main body of the detached axis, R the road (not to confine it while turning the gun, but to ſupport it when the gun is taken away), and S the ſquare ſocket, that receives the ſquare at the breach of the gun, by which it is turned round; the two arms in this figure being marked with the reſpective letters, as the correſpondent ones fig. 1 and 2, will receive a ſufficient explanation, eſpecially when it is obſerved further that T is a ſtud caſt upon that arm, which is acted upon by V, a ſtrong ſpring ſufficient to give the arm E F G a conſtant tendency to go towards the arm A B, and *n o* in dotted lines is a ſtaple to ſtop the ſtud and ſpring from riſing too far, and from carrying the arm beyond its due poſition.

Now *p q* repreſents the kamm of the arm F G, and *r s* repreſenting the kamm of the arm A B, which overlaying one another, the arm F G will neceſſarily be compelled to go round with the arm A B ſo long as they remain in this poſition; but to diſengage it, the outlaying part of the arm E F meeting in a certain part of its revolution with an inclined plane (of wood faced with a plate of iron) that can at pleaſure be interpoſed, this plane or wedge by acting upon the outlayer ſo as to ſeparate the two arms, the kamms will be releaſed from each other, and the outlayer, reſting upon a projecting part of the wedge, will remain at reſt, the other arm continuing its revolutions. The gun is then to be removed as at preſent, and when another is adapted to the ſquare at S, there is nothing to do but to draw away the inclined plane or wedge; the ſpring throws

 out

out the arm F G ſo as to form a right angle with the axis, and the next time the kamm $r s$ meets the kamm $p q$ it will quietly lay hold of it, and take it along with it, and ſo continue till diſcharged as before.

N. B. It is neceſſary that the edges of the kamms at the leaving each other ſhould be parallel; for this reaſon they muſt not be ſquare, but inclined according to the line $r t$; nor muſt the edges be quite ſharp, but a little rounded; and as the continual chafing of the guns may wear the ſocket S faſter than might be convenient, this ſocket may be caſt with a citadel head large enough to incloſe a piece with a common ſquare within it. If the ſtrength of the ſpring is not found ſufficient to keep the arms together when in full ſtrain, it is only making the kamms a little proud at the leaving edges, ſo that being a little matter out of parallel with the axis, they may be made ſo as to draw themſelves together.

EXPLANATION of the Apparatus for holding and puſhing forward the boring bars for the carronades without a carriage.

A B C D is the ſection of a ſquare ſocket of caſt iron, 5 inches ſquare and 2 feet long, which is to be firmly bolted down upon a proper blocking of wood.

E F is a ſquare of iron of the ſame ſize, and 2 feet 2 inches long, which muſt be fitted to the former with ſome degree of curioſity, ſo as to ſlide eaſily, and with as little ſhake as may be; this ſolid piece is to have a tapering ſquare hole at each end, proper to receive as a ſocket the ſquare of the boring-bar. This would in reality only be needed at one end for fixing the bar G G; but as it may be ſubject to wear, the laſting will be doubled by having a ſimilar ſocket at each end.

At the oppoſite end of the ſolid piece, the piece H is inlaid for receiving the point of the ſcrew I K, by which the ſolid piece and bar are to be forced forwards. L M N is a lever of wood, footed at bottom in two ſtrong ſtaples O P, one on each ſide; the lever L firmly bolted and ſupported by the ſolid blocking.

Q is a braſs or a wrought iron box for the ſcrew, hung upon trunnions as q, ſo as to give liberty to the threads of the box cloſely to fit and embrace the ſcrew, notwithſtanding the different poſition of the lever L M N.

N B

N R is a bar of iron, by which the top of the main lever is connected with a secondary one, whose center of motion is supposed to be at S, and which going upwards beyond the limits of the paper, is represented to a smaller scale *s r t*, where there is attached a single block with an 8 or 9 inch light sheave, and a rope of about 2 inches circumference being reeved, as shewn and passing over the fixed pulley *v*, the weight W will force the point of the screw against the piece H with any degree of force required; and as I don't expect the great lever to work kindly, when more than 1 inch out of perpendicular at the height of the screw, this will give it leave to act by the weight through a space of about 2 inches, when the person attending setting forwards the screw by means of the fixed bar T X, brings up the lever and weight into its original position, and so on, till the bore is carried on to its proper length. The apparatus, in the proportion here designed, will admit of a chase of near 30 inches length, which, I apprehend, will be fully sufficient for your 24 pounders.

N.B. I am told, that a bit, whose cutting edges are brought to a proud edge by being filed to an hollow, as is shewn at *x y*, is marvellously good for boring holes in cast iron; but in this case the two edges cannot be brought into one, but the obtuse angled edge, formed by the thickness of the metal of the bit, joins the two cutting edges crossways, and forces itself forwards by being near the center, but requires a considerable pressure. I am told that 800lb. weight will be required to bore an inch hole; and though these hollow edged bits are not so well adapted to continuance of grinding as plain ones, yet make full amends by their much less frequently wanting sharpening. How far this kind of bit may be adapted to gun boring, I leave to your trial.

Austhorpe, January 9, 1779. J. SMEATON.

EXPLANATION of the Sketch, shewing the manner of applying the inclined plane for releasing the work of the discharging apparatus for the carronades.

Fig. 2 shews the same face of the work as is shewn in fig. 2 of the design for the discharging apparatus sent before, wherein E F G is the discharging arm, and V W is an upright piece of wood capable of sliding up and down, but in no other direction, and the same letters denote the same thing in the side view thereof, fig. 1. to which is attached or made out of the same solid X Y Z, the inclined plane or wedge. In the

present

present position of it, it is in a posture for acting upon the discharging arm, and is kept up by means of the catch *m n* dropping into a notch under the piece of iron at O, when the arm E comes into the position *e*; it then begins to touch upon the inclined face X Y, and going forwards, by degrees gets discharged before it comes to the position *p*, which shews it discharged and resting upon the pin *q*, where it remains till the gun is shifted, and the rotation is wanted to be commenced; then the catch *m n* is drawn back by a cord, which lets the piece V W drop, till the line X *e* goes down to the line *q r*, viz. about $16\frac{1}{2}$ inches, which entirely clears the discharging arm, and then its own spring brings it into its working position, where the next time the revolving arm meets it, takes it along with it, and the motion will be continued till the piece V W is drawn up again by a cord, lever, or other equivalent contrivance, till it is supported by the catch *m n*, when at the first meeting it will be discharged as before.

J. SMEATON.

Austhorpe, January 9, 1779.

EXPLANATION of the Design for turning Shot Moulds.

THE semi-circle A B C, fig. 1st, is supposed to be the horizontal section of an half mould, seen from above, which, together with C, *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, A, is supposed to compleat the whole of the section, and is supposed to be properly fixed upon the arbour or mandrell of a stout chock lathe, capable of turning it with steadiness.

D is the center of the sphere, and, upon an axis passing perpendicularly through this center a frame is supposed to turn, that carries the tool, so as to describe the quadrant A B, and by that means the semicircle A B C, *i*, *k*, *l*, *m*, is the upper surface of the cutting-tool, *l m* being the cutting edge. Now if the edge *l m* be formed into an arch of a circle, whose radius is less than the sphere to be described, and whose center (suppose at *n*) is capable by the inclination of the frame to be brought into the radius line A D, then it is evident, that if, while the mould *f c d e* turns round its axis D B, the tool, by gradual inclination of its frame, passes from A to B, the tool will cut off all superfluous matters that projected beyond its sweep, and also in case the cutting-edge of the tool is regulated to a just height, so as to pass through the center of motion of the mould at B, then it is plain that the hollow figure thus described must be an exact hemisphere.

Nothing

Nothing can be more evident and simple than this proposition, the whole difficulty consists in having those exact adjustments that are requisite to perform the necessary conditions, and, at the same time, all the strength and steadiness in the framing that is necessary to work upon and cut clean a mass of cast iron; for this purpose

E F is a section of one cheek, and G H that of the other, of a mortice through the solid metal, for lodging the tool *i k l m*, and the prolongation G K is for the reception of an hollow wooden handle, sufficiently long for turning the frame steadily round upon its axis, while the cutting-edge of the tool is describing the quadrant A B.

Fig. 2 shews an upright section of the mould, wherein the same letters denote the same things as in the former figure, *i m* now shewing the upright of the tool whose cutting-edge is at *m*, this is pushed towards it works by the screw *o p*, which passes through the stud I, affixed to the projecting part G K, and the tool is tightly held down in its mortice or socket by L M, a wedge, which last is slacked or drawn out by *q*, a counter wedge. The socket G H, the prolongation or tail G K, are cast in one solid piece with N O, the upright axis, and those with the projecting ears Q Q, which are supported by and turned round upon the points of the screws R S, by which means the frame is made capable of turning round upon the line R C D A S, passing through the center of the hemisphere A B C, at the same time that the frame will clear the face of the mould when in its most inclined position, as is shewn in fig. 1; where observe, that the dotted square G N shews the section of the upright axis above and below the socket, as at N and O, fig. 2, and the dotted space G N Q, fig. 1, shews the figure or plan of the ears at top and bottom, where they engage with the points of the screws R and S.

Fig. 3 shews the fore front of the mould in the lathe, and the same letters will denote the same matters, besides which T V W X Y Z, &c. denotes a strong frame that surrounds the whole mould, and supports the screws R S upon which the upright moveable turns upon as a center, as already described, which outward frame is to be firmly bolted down upon its flat base upon a stout plank, which plank is to be made to slide with ease and certainty between the cheeks of the lathe, so as to move in a line parallel to the axis of the mandrill, and to fix at any distance required from the end of the mandrill. It is also supposed, that the axis of the mandrill is adjusted as nearly as possible to a parallelism with the cheeks and platform of the lathe.

Now the first necessary condition and adjustment is, that the height of the cutting-edge of the tool shall exactly pass through the center of motion of the mould, which will

will beſt be done by trial, becauſe if it leaves no extuberance in the center, it is plain it has paſſed through it; if an extuberance is left, it muſt be by paſſing either above or below it, and which of them it is may be ſeen, and the moving frame ſet higher or lower, by ſlacking one and tightening the other of the ſcrews R S, and repeating the trial till the ſurface is left without an extuberance in the center.

The ſecond neceſſary condition and adjuſtment is, that the line joining the points of the ſcrews R S ſhall paſs through D, the center of the ſphere, that is, through the axis of the mandrell produced, which will alſo be beſt known by trial; for this purpoſe, let a gage circle be turned from thin plate braſs to the intended diameter of the ball or ſphere of the mould; turn out alſo the central part of the area, leaving it a ring about $\frac{3}{4}$ or $\frac{5}{8}$ of an inch broad, and cut this in two, which will thereby make two gages: thus provided, let a ſweep be made for trial, and it will be known by the gages fitting the ſweeped ſurface whether the cutting edge of the tool is at its proper diſtance from the center, becauſe then the gage will fit the ſweeped ſurface when directed towards the center; if not, let the tool be ſet forward by the ſcrew *o p*, till they perfectly agree, then running the gage through the center and *beyond* it, if the gage bites hard upon the further quadrant, then the axis of R S is beyond the axis of the mandrell; but if the matter beyond the center leaves the gage, then it is plain that the axis of R S is on the ſide of the axis of the mandrell that was the cutting ſide of the mould, and, accordingly, this is corrected by ſlacking the ſcrew *r r*, and tightening the ſcrew *t t*, or the contrary, till a ſweep being taken, the gage every where applies itſelf to the hollow ſurface of the mould; and this adjuſtment being once performed, there is nothing but gradual wear or violence to put it out again, and the gage being applied to every mould, it will always be ſeen whether any apparent error gradually ariſes.

The ſcrew *r r* acts upon the ſtud S, and the ſcrew *t t* upon the ſtud V, both of which are caſt upon the ſame piece of metal with T V, which carries the ſcrew R, and ſlides ſideway in a chamfered groove in the upper bar of the outward frame, as is more particularly ſeen in fig. 2. I have deſcribed the ſame kind of ſlide at the bottom Z S, &c. but this is ſcarcely neceſſary; for if the whole frame is bolted down upon the ſliding plank, ſo that the line R S may originally be nearly right, when T V is in the middle, the adjuſtment may be ſufficiently performed by ſliding the ſcrew R only, for it is no ways requiſite that the line R S ſhould be exactly perpendicular; but only that it paſſes exactly through the axis of the mandrell produced, but it will be neceſſary that both the ſcrews R and S ſhould have a counter nut, as at the dotted lines *w w* and *x x*, unleſs they are made to ſcrew ſtiffly through their carriage-pieces.

It

It is to be observed, that, on changing the size of the mould, there ought to be nothing wanting in the way of adjustment, but to set the cutting edge of the tool to its just distance from the center; and as the tool changes in its height by grinding, or a different tool, to see that it passes through the center, that is, supposing the slide of the plank duly performed; and as, upon this slide's being correctly performed, a great deal of the ease and facility of the use of this machine will depend; and as this correctness may seem difficult to arrive at, I will take occasion to make an observation upon lath-making, which may apply itself to several other things in the *Carron* works. To make the heads, &c. of a lath to slide in a right line between the two parallel cheeks with ease and facility, and without vaccilation or shaking, is in reality no easy matter to perform; but if the near upright face of the further cheek is shot true and straight with a plane, and the upper face or platform of the two cheeks shot straight and flat, that is, out of winding, all which in carpentry is an easy proposition; if then all the matter composing the seat of the heads is cut away or hollowed off, except about the value of $1\frac{1}{2}$ or 2 inches square, at the four corners, and these prominences brought to a just flat, so as to fit true without shake upon the platform of the lath; if also the far side of the tenant is made to take its bearings at the outsides, so as to apply itself fairly and steadily to the far cheek of the lath; then, if the heads (or any other sliding piece formed in this way) are pushed home against the far cheek with one hand, at the same time that the wedge or screw is tightened by the other, it is plain that these heads or sliders will obey the same right lines that form the upright face of the back cheek and platform, and it is then no matter whether the tenant fills the groove or not, but when slacked will be always at perfect liberty. It seems hardly needful to say, that for correct work the cheeks of a lath should not only be made of dry seasoned wood, but clean and free from cross baits, to prevent their warping after made.

N. B. I am not well acquainted how well the *Carron* metal works with a file, but, to avoid all intricacy and trouble in forging, I would chuse the work to be cast of gun-metal, or perhaps what may be better, 1 ounce of tin to 1lb. of copper.

The mould being supposed hollowed to a true sphere, but a little too deep, then there will be nothing to do but to turn down the face of the rabbat *b* A C *a*, till the depth D B is exactly half of the width A C, and then two such will form a sphere.

It is plain from the figure, that to give the tool a proper bearing in its socket, that one upright frame will not do for all sizes; the present one is drawn at large to answer any size, from a 24lb. shot to a 9lb. another one will go from that to a 3lb. under which it will be proper to have one of a proportionable size; but they will all apply themselves to

 the

the screws R S, and without any other adjustment than that of height. I must, however, observe that the screws R and S must, in proportion to their size, be cut with a fine thread and with sharp stocks, that being first truly turned, they may not cast in stocking, so that when turned round in their sockets, their centers will not sensibly vary. This is a matter requiring attention, but being duly attended to, is not difficult to be practically performed.

J. SMEATON.

Austhorpe, 16th January, 1779.

EXPLANATION of two methods of raising the Slide Carriages for the Carronades.

Fig. 1. A B represents the slide carriage plank.

C D. a piece of wood bolted on crossways upon the under side; this transverse piece is pierced towards each end by a female screw capable of receiving a male screw, one of which is denoted by

E F. a wood screw 10 inches long in the screwed part, and 2 inches long in the head part F, which is well bound with an iron hoop, and perforated crossways with a couple of holes for small handspikes. The position here shewn of the slide plank is horizontal, or parallel to the deck, which, according to the sketch sent, its under side in that position was 12 inches, and in this position the part of the screw shewn clear, viz. F G, is 4 inches; so that when the head F comes close to the tranverse piece C D, the end A will be lowered 4 inches, and then the top of the screw will just reach to the upper surface of the slide plank, but without reaching through, so that the hole cut through it to clear the screw, may be covered with a thin plate if thought necessary; but if the screw is unscrewed 4 inches more than is shewn in this position of the figure, so that the top of the screw E will come down to H, then the end A will be raised 4 inches higher, and yet the screw will have 2 inches hold of the box, which, containing three threads, will be sufficient to keep it steady.

Fig. 2. A B represents the slide carriage plank as before; C D shews one of two planks, bolted edgeways under the carriage plank, cut into 6 steps *a b c d e f*, each 1 inch in height, and 2 inches in breadth.

E F

E F shews a piece of wood seen endways, long enough to take both the stepped planks, and stepped also into 6 steps, *g h i k l m.* Now if the height of the lowest step *g* is 4 inches, and increase by 1 inch, then it is evident, if this stepped wood is drawn gradually back, the plank A will descend 1 inch at a time, till the step *g* comes under the step *e*, and the step *h* under the step *f*; then will the end A have descended 4 inches; but if from the present position the stepped wood is pushed in one step at a time, then the end A will rise accordingly, till the step *m* being under the step *b*, and the step *l* under the step *a*, so that the plank A, or rather the point *a*, will be raised 4 inches; and if it is thought expedient to keep them from jumping out of their places, the small staples *n o* being struck in at each end, and the parts lashed together with a marline, this will be sufficient to keep them from shifting the steps upon a discharge, as I apprehend.

J. SMEATON.

Austhorpe, Jan. 20, 1779.

EXPLANATION of the Design for a new Nose-Pipe for *Carron.*

Fig. 1. A B is supposed to represent the fire stone that now makes the tuire of the furnace, which is supposed to be of the accustomed thickness, but perforated with a round hole of 7 inches diameter, or of such other width as it may be thought proper first to try.

C D E F shews the horizontal section of an iron tube serving for the nose-pipe, also of 7 inches diameter, and checked into the stone, and the joint made good with fire clay, which round tube branches out sideways into

C G H and D I K, which are the sections of two oval tubes, whose axis M L and N L meet the axis of the main tube at L.

O P Q R represent two dove-tailed sliders, that shut up the orifices of the oval side tubes, so as to be air tight; those oval openings are proposed to be 4 inches wide by 6 inches high, so that on removal of the sliders every part of the opening of the tuire into the furnace may be seen, and the arm and instruments introduced by which it may occasionally be luted, and when shut the wind will take its course from the part of the tube E F towards C D, in a parallel direction.

 N. B.

N. B. About 8 or 10 inches of the external part E F is proposed to be kept of a width, but from thence to increase gradually tapering to the size of the main conveyance pipe.

Fig. 2 represents an upright section of the main tube at the line S T upon fig. 1.

E F is the main tube.

O P shews the oval hole with the slider drawn out.

Q R represents the slider in its place, wherein, if thought convenient, *v w* in both figures represents an hole, whereto a piece of plate glass being adapted, and fixed in each slider, the condition of the tuire may, at all times, be inspected, without drawing the sliders, or disturbing the blast.

J. SMEATON.

Austhorpe, May 2, 1779.

A Comparative View of the State of the *Carron* Furnaces in October, 1776, and in September, 1778.

	No.	Gate drawn.	Head of Water.	Diameter of nose-pipe.	Number of Cylinders.	Cube feet of air per minute.	Velocity per second.	Tons of water expended per 24 hours.
State of Furnaces, October, 1776.	1			2¼	28	1571	947	16,502
	2			2½	24½	1708	835	16,047
	3			2 7/16	19	1343	691	15,732
	4			2¼	12[illegible]	1459	881	17,769
					Sums	6081	3354	66,050
					Means	1520	838	
			ft. in.					
State of Furnaces, September, 1778.	1	1¼	3 7	2¼	25	1402	846	16,322
	2	0⅞	4 8¾	2½	16	1116	546	11,724
	3	1⅜	3 10½	2 7/16	17½	1237	562	15,286
	4	0¾	3 0½	2¼	20½	1309	529	7,396
	6	0⅝	3 1¼	2¼	21	1341	542	6,630
					Sums	6405	3025	57,358
					Means	1281	605	

From

From the preceding table there appears a great improvement in the dispensing of the water, for in the year 1776 four furnaces expended 66,000 tons per 24 hours, and in the year 1778 five furnaces expended but 57,300.

It is, however, remarkable, that of the last-mentioned quantity, numbers 1 and 3 expended 31,608 tons per 24 hours, while the other three furnaces expended but 25,750, the cause of which disparity it may be proper to enquire; for though every degree of accuracy, I doubt not, has been exerted in the new building of No. 6, and the rebuilding of No. 4, yet there is not that difference in the principle of action that can make these two machines so very much exceed those of No. 1 and 3; for in point of construction I should not expect them to fall short of the performance of No. 4 and 6 more than 20 per cent. This difference I must therefore attribute in a great measure to the different widths of the nose-pipes, which, as I have never heard of their being varied, I take for granted they continue the same they were in the year 1776, that is, as I have put them down. And I have no doubt but that if they, as well as No. 2, were furnished with the same kind of nose-pipes that No. 4 and 6 blow with, that they would then perform within a reasonable difference of those last furnaces; if not, the rest of the difference must be sought for elsewhere, that is, either in the untruth of the cylinders, too great friction of the leathers, a straightening of the wind passages, or a general disrepair of the machines; all which are matters well worth looking into; for if two furnaces can be worked with 14,026 tons per day, this is less than the average quantity for each of the other three, which is 14,444.

Again, although it appears that the expenditure of No. 2 is greatly reduced, owing in part to the removal of Mr. DOWNING's incumbrances, and in part to the reduction of the number of cylinders per minute, (which I suppose was also a consequence of the restitution,) yet if the expenditure of No. 2, viz. 11,724 tons per day, be reduced in proportion of 23 to 20 (which would certainly be the case if that wheel was raised to 23 feet high, like Nos. 4 and 6,) it would still expend 10,195 tons, which is 2799 tons per day more than that of No. 4; and as there does not appear to me any other thing in the construction of the machine No. 2, that should make it fall short of No. 4, this extra expenditure by No. 2 remains to be accounted for, and which in part I doubt not is owing to the difference in its nose-pipe.

That the difference of the friction of the leathers is capable of considerably varying the expenditure of the water, I think appears pretty plain from Nos. 4 and 6, the former consuming more water by 11½ per cent. upon the lesser quantity, than the latter does; and therefore, as they are both as nearly alike as possible, the No. 4 being the last

built

built furnace, it seems most probable that the sides of its cylinders were not at that time got to so great a smoothness as those of No. 6, or that casually No. 4 was at that time harder in its leathers.

Now, if we suppose Nos. 1 and 3 to be reformed so as to perform within 20 per cent. of No. 4, and No. 2 reformed so as to perform as well as No. 4, then the expenditures will stand as follows, viz.

No. 1,	8875	No. 4,	7396
No. 2,	7396	No. 6,	6630
No. 3,	8875		
			39,172

From this statement it appears probable, that the consumption of all the five furnaces may be reduced to 39,172 tons per 24 hours; and as *Carron* furnishes in dry seasons 26,400 tons (see report of 6th April, 1777,). there will then only remain 12,772 tons per 24 hours to be provided for out of the reservoirs; and as it is stated in the same report that the home reservoirs alone contain, upon three feet depth to be drawn off, a treasury of 164,268 tons, this would supply *five* furnaces at the rate above stated for near upon 13 days; whereas the same quantity, according to the view of the subject at that time, was not likely to serve *four* furnaces much above seven days. But further, in case No. 1 or No. 3 were laid off in times of scarcity, or that they both together were allowed but 8875 tons per day to keep them alive, then there would be only 3897 tons per day to be provided for out of the reservoirs, which would last the furnaces at this allowance full six weeks, which, together with the other command of water the company already have, seems to render the building a fire-engine of any construction totally unnecessary, especially if the old engine is kept in working order to serve an emergence.

For some time No. 1 led the van of all the works, now it is got into the rear of all; but if you had an opportunity of applying the nose-pipe I transmitted in my letter of the 13th ult. I have reasonable expectation that this furnace would once more lead the van.

J. SMEATON.

Austhorpe, June 11, 1779.

The

The REPORT of JOHN SMEATON, Engineer, concerning the expediency of opening the temporary Cut and Lock near *Dalderse*, from the canal of *Forth* and *Clyde* to the river *Carron*.

THE utility of this cut, from *Carron* ſhore and parts adjacent, appears from its firſt conſtruction, which was to bring the ſtones got from the quarries at and near *Kinnaird*, and brought down by the coal waggons to *Carron* ſhore, there put on board ſmall lighters, was brought through the temporary cut, and brought to build the firſt land lock, and other works in that quarter; alſo the lime, pozzelana, and timber were brought for ſome time that way; and it being a work ordered by the Committee, principally by the advice of Mr. MACKELL, he urged in favour of its expediency, that it would be the propereſt accommodation to the *Carron* works, and that (in his way of expreſſing himſelf) that Company ſhould never get any other. From this it will appear (which I perfectly remember) what were Mr. MACKELL's ſentiments concerning it at that time. On examining it, which, at the requeſt of the *Carron* Company, I did the 6th of November laſt, I found both the cut and lock to all appearance in much better condition than I expected; the principal thing wanted to reſtore it, will be a little more room, to get earth to ſtrengthen and heighten the banks, equivalent to thoſe of the main canal; and reſpecting the lock, for any thing that appears, it ſeems to be likely to want little for ſome time to come, more than new gates; and the lock is of ſo ſmall a ſize, that the head of the lock may be ſhut by a ſingle gate, in ſuch a way as to occaſion much leſs leakage than the larger pointed gates, and in a mode that I firſt put in practice upon the river *Calder* in or about the year 1761, and which the laſt December I had the pleaſure to ſee in perfect good order, without having had any derangement or repair.

The conſtant leakage being in this manner ſecured to all ſmall veſſels, having a right to paſs the canal proceeding ſingly upwards, as much water will be ſaved to the laſt, or ſea reach, as is equal to the difference of area between the temporary lock and the canal locks, which is much more than double, and will be more than equivalent to the conſumpt of ſuch veſſels as may happen to have occaſion to go downwards, from the temporary cut; beſides, as this reach is of a conſiderable length, and pretty capacious, and naturally receives the regulating water, and all the leakages from above, there is the leaſt fear of wanting water in this than any other of the reaches.

I remember

I remember myſelf that this accommodation was frequently mentioned as proper for the *Carron* Company, but which at that time they did not think ſufficiently commodious, and near their works.

As therefore it appears likely, that by opening this temporary cut and lock, there will be a conſiderable increaſe of freight and tolls, without any loſs, that it will, for the advantage of the whole, be a proper meaſure to be carried into execution.

Auſthorpe, 7th February, 1782. J. SMEATON.

N. B. I apprehend that ſmall veſſels will generally paſs ſingle, for it is to avoid waiting for freight that larger veſſels are not uſed.

To the CARRON COMPANY.

GENTLEMEN,

IT is from what has occurred to me in the experience of 30 years in the profession of civil engineery, that I have long entertained an idea that cast iron anchors, I mean those of the largest sizes, would be found of equal if not superior strength to those of wrought iron; and, though in a case where not only the lives of men, but the welfare of nations is concerned, no mercantile consideration ought to take place, nor ought any thing to be spared that can add to the perfection of so very material an utensil as that of the anchor; yet if, upon a fair and full trial, it shall appear that cast iron ones, of a proper composition of metal, are in reality equally or preferably to be depended upon, then the readiness, cheapness, and facility wherewith they are to be produced, appears to me a very sufficient reason (to say nothing of the encouragement of a *British* in contradistinction to a foreign production) why such a fair and full trial should be made as shall be sufficient to put the matter beyond a doubt.

I never supposed that any kind of cast iron would be equal in bearing a stress with that of wrought iron, even of a tolerable quality, provided the size and shape of the matter to be formed of wrought iron is capable of being firmly welded, and united in one solid mass; for this reason, I cannot suppose any anchor can be formed of cast iron, that shall bear a stress equal with one of wrought metal, whose shank is in the smallest part not more than 3 inches, or $3\frac{1}{2}$ inches in diameter: but observing in such large anchors for first and second rate ships of war, as I have had the opportunity of seeing when broken, that the wrought bars of which they are composed are very imperfectly welded and united together in the inside; and having also experienced on the other hand the very great strain that large masses of well-mixed cast iron will bear, when applied to the greatest stresses in mill and engine work, I have been naturally led to put the query, whether beyond some certain medium, that is, whether in those very large and heavy anchors for the largest ships, the substitution of cast iron, instead of wrought, may not be in every respect useful and advantageous.

Had the trial you have communicated to me, made by the officers of his Majesty's yard at *Deptford*, appeared to me conclusive, I should have there rested the matter with them, as fully and sufficiently tried; but, with all due deference to those gentlemen, whose knowledge in their profession entitles them to the greatest respect from the public, I beg leave to say, that this is a new case, and therefore till it is tried, in a manner similar to that in which it is to be used, it is in fact no trial at all.

Had the proposition been to try whether a wrought or a cast iron anchor, or indeed a bar of metal of any size, would best bear the blows of an iron ram or beetle, the mode of trial was perfectly adapted to prove the point; and I am so far satisfied of the fact, as it turned out, that I even wonder that the palms were not broken by the hammers; but I conceive there is nothing like the collision of hard bodies in the real use of an anchor at sea; on the contrary, no stress can possibly be communicated more kindly than that of a ship to its anchor, through the intervention of a long cable. It is possible, in letting go an anchor, it may fall upon a rock, but I conceive an anchor is never let go in foul ground by design, and by choice, but yet it may happen and be necessary. The anchor in its descent having necessarily the cable to haul out after it, and the stock of the anchor, like the log, to haul crossways through the water, the velocity natural to the descent of heavy bodies is hindered from taking place in so great a degree, that let the water be ever so deep, the velocity wherewith it strikes the ground is very moderate, and with this further circumstance that must attend it, that, from the anchor stock and cable both conspiring to act as a rudder, the anchor will necessarily fall with its shank near a perpendicular direction, and therefore have the best chance of impinging upon some part of the crown that is fortified in the best manner to resist blows, as well as every other violence; besides, the rocks below the surface of the sea, being supposed a continuation of the strata above it, and nearly of the same hardness, they are comparative to iron generally soft bodies, and the hardest of them all that lay in masses in this kingdom, that we know of, would, by such a stroke, be *bruised*, less or more; and this is certain, that the effect of a stroke, where either of the bodies is bruised, or will rebound by elasticity, is widely different from what will happen when neither of them will give way in a sensible degree; I must therefore conclude, that there is not, nor can be, any thing in the real use of an anchor that is in any degree analagous to the stroke of an iron ram, much less to such a stroke applied crossways upon its shank.

The windmill, axis and oil-press that you cast for me the year before the last, the former has withstood the fury of all the storms that have happened since, without the least likelihood of injury; and yet one blow of the *Deptford* piling-ram, properly directed, would destroy it. The oil-press is in constant work, and every five or six minutes is subject to an alternate pressure and release from it equivalent to 300 tons of dead weight, tending directly to rend it in two; and yet I believe a single well-directed blow of a sledge hammer would break it. If the length of time of the use of these utensils is not thought sufficient, I must add, that in the year 1755, that is 27 years ago, for the first time, I applied them as totally new subjects, and the cry then was, that if the strongest timbers are not able for any great length of time to resist the action of the

powers,

powers, what muſt happen from the brittleneſs of caſt iron? It is ſufficient to ſay, that not only thoſe very pieces of caſt work are ſtill in work, but that the good effect has in the north of *England*, where firſt applied, drawn them into common uſe, and I never heard of any one failing. Your own method of breaking up the largeſt iron guns is alſo an example to the ſame purpoſe, where the blow ariſing from the fall of an iron ball of 7 or 8 cwt. produces an effect that ten times the power of gunpowder would not; for the action of powder, though very quick, yet differs from the inſtantaneous action of a blow, in much the like manner as a line does from a ſurface.

The mode of trial that would appear to me concluſive would be as follows: I would take two anchors, as nearly of a weight and dimenſions as poſſible, the one of wrought, the other of caſt iron, not leſs than three tons weight each (two tons I think too much in favour of the wrought iron for a *firſt trial*,) and placing them at a competent diſtance in a right line, with the rings towards each other, for each I would dig a pit in the firm ground, capable of burying both the palms of each anchor: at the bottom of each pit I would fix, edgeways upward, a large elm plank of 10 inches or a foot thick, into the middle of which I would make a moderate perforation of about 3 inches, to receive the point of the fluke of each anchor; theſe planks I would guard with piles in the ſecureſt manner poſſible, to prevent them, on the application of a great preſſure, from moving towards each other, and then well ramming up the whole with earth, ſo as to bury the anchor, the ſhanks of each to be inclined upwards, ſo that the rings may be at or near the ſurface.

Then having provided two pair of purchaſe-blocks capable of purchaſing 15 or 20 tons each, with ſuitable tackle-falls, and cap-ſtands, crabs, or tooth and wheel gins, I would hook one block of each pair to the ring of one anchor, and the other to the other, ſecuring every thing as much as poſſible; and the tackle-falls being made to go off to the capſtands, each by a ſnatch block ſideways, it is plain, that whatever ſtrain is upon one anchor, the ſame will be on the other; I would then proceed to heave till ſomething gave way, and which ever of them kept the ground, after the other, by failure, was drawn out of it, would be the anchor upon which I ſhould be ready, in caſe of the greateſt extremities, to pin my faith.

The expence of the trial I ſhould think no object, for in caſe the caſt-iron anchor was broke, and the other unhurt, there would be no loſs but of a little labour, and was I to go to ſea, I ſhould chuſe the anchor that had been ſo ſeverely tried, in preference of all others of the ſame ſize and kind; but if the wought iron one gave way,

by

by binding or breaking, so as to quit the ground, while the cast-iron one remained unhurt, then a discovery will result worth the price of 20 anchors.

In this manner, if the cast-iron anchor proved the conqueror, I would proceed to try those of a lesser weight, so as to find somewhat nearly the medium, at which the wrought iron anchor would have the preference, keeping always on the safe side of the question.

These, gentlemen, after full consideration, are the result of my genuine sentiments of this subject, which you have desired; and if found useful towards determining a point that may be of much utility to the public service, shall think my pains and study well employed, and remain,

Gentlemen,

With much esteem and respect,

Your most humble servant,

Austhorpe, February 7, 1782.　　J. SMEATON.

END OF VOL. I.